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CHARLOTTENLUND SLOT – DANEMARK

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E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

DÉCEMBRE 1939

Notice.

The Journal of the Council appears *three times a year*, and three numbers form a volume. It includes, in addition to general articles, reviews, and bibliography, the special papers previously issued in the series of *Publications de Circonstance.*

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Special Note.

An effort will be made to continue publication of the *Journal du Conseil* on a reduced scale during the War, and contributions in the form of scientific papers, reviews and abstracts will be welcomed.

Until further notice, contributions should be sent to the Honorary Editor, Dr. E. S. Russell, Dolphins, Northchurch Common, Berkhamsted, England.

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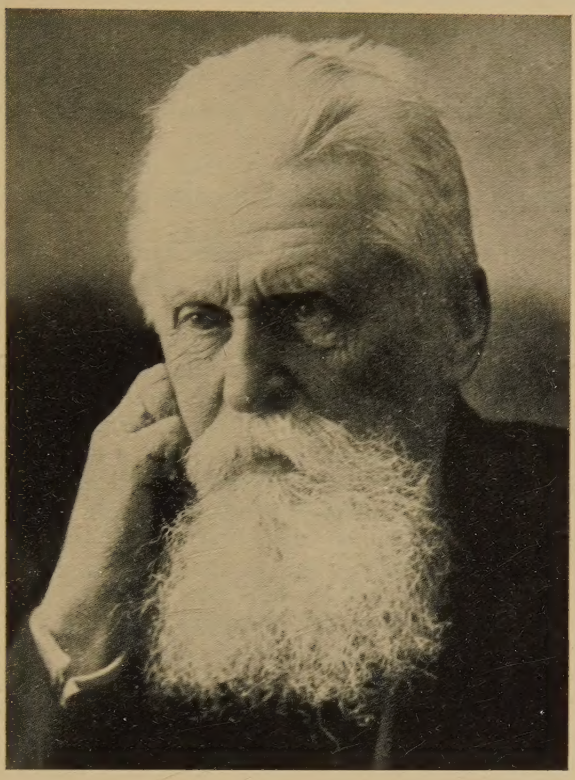

N. M. Knipovich.

1862—1939.

THE Delegates and Experts of the International Council, and especially those who have collaborated with Professor Knipovich for many years, at sea as well as at meetings, have learned with deep regret that never again shall they meet.

Knipovich was Russian Delegate to the International Council during the years 1901 to 1913 and Vice-President from 1913 to 1914. During the early years of this century it was my good fortune to co-operate with him in the Barentz Sea where he carried out important work of a hydrographical as well

as a biological character. He was the first, I believe, to prove that the Atlantic current divides into various parallel branches which, partly at the surface, partly in middle depths, continue far eastwards into the Barentz Sea, where they are of great importance in relation to the distribution of the fauna. Also, he was among the first to announce the extremely important climatic change north of Norway and in northern Russian waters actually experienced during the last twenty years, which has caused changes in the distribution of the currents and the drift-ice. Effecting increase in temperature the more saline "Atlantic Water" has proceeded much farther north and east — a fact with which Knipovich connected an immigration of organisms not hitherto recorded at these latitudes.

Through these observations and the clear comprehension of their importance Knipovich has contributed largely to one of the great future problems of the International Council. Space does not permit mentioning in detail a life spent in the service of science — in Arctic waters as well as in the Black Sea — we can only remember the co-operation of Knipovich with gratitude.

Johan Hjort.

Kirstine Smith.

12. IV. 1878 — 11. XI. 1939.

WE regret to announce the death of Miss Kirstine Smith, formerly hydrographical assistant to the Council (1904—1913), which took place in Copenhagen, on November 11th, at the age of 61.

The Effect of the Closure of the Zuiderzee on Fish and Fisheries.

By

H. C. Redeke,

Utrecht.

ON May 28th, 1932, the closure of the Zuiderzee was completed. With the filling of the last gap in the dike, stretching in a north-easterly direction from the isle of Wieringen to Zurig on the opposite Frisian coast, one of the richest fishing grounds of north-western Europe had for ever lost its open communication with the North Sea and became a lagoon, filled with almost fresh water, much larger than any of the other inland lakes of Holland but otherwise of the same type.

The radical shutting off from the North Sea brought considerable changes in the enclosed area in both hydrographical and biological respects and consequently the fishery conditions have completely altered in the course of time.

The aim of this paper is to describe the changes in the natural conditions of the Zuiderzee and its successor, the IJsselmeer, owing to the enclosure, and the influence of the different factors on the impoverishment of its stock of marketable fishes.

Hydrography.

The Zuiderzee originated from inundations in the fifteenth century and has since showed the character of a large and shallow estuary. The southern central part, with a fairly uniform depth of about 3 m. and a soft muddy bottom, was separated from the northern part by a narrow channel between the coasts of North Holland and Frisia. Here the bottom consisted chiefly of coarse sand, with the exception of the western area south of the isle of Wieringen; this area is now embanked and drained, and made suitable for cultivation and for habitation. The funnel-shaped northern part, once the boundary zone to the North Sea, is now crossed by the huge closing-dike which prevents the sea water from flowing in. For navigation and the outlet of surplus

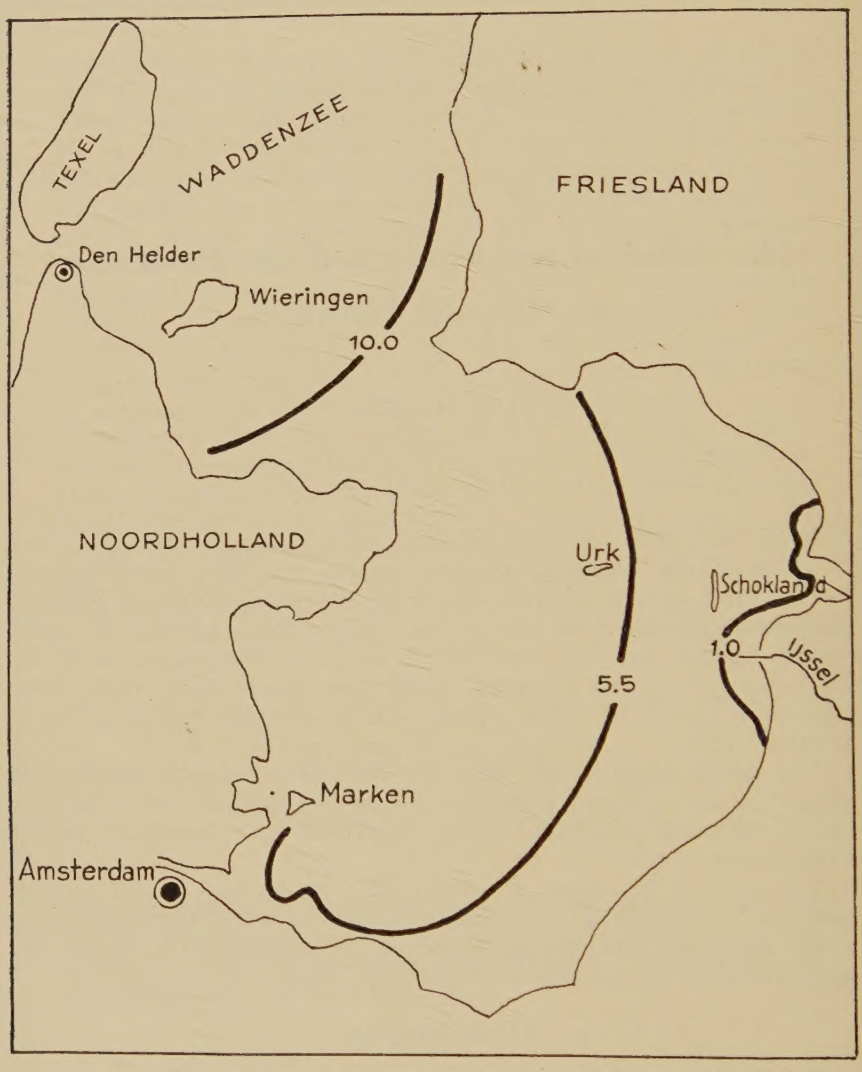

Fig. 1. Normal Isohalines (Cl $^{0}/_{00}$) of the Zuiderzee.

water in the IJsselmeer sluices have been built both on the Holland and on the Frisian side.

In the large shallow basin tidal action was slackened, so that currents were hardly perceptible, but the water was often stirred up by winds and consequently was as a rule very turbid.

Before the closure the three zones of brackish water were well represented in the Zuiderzee, (1) by a narrow oligohaline stretch along the south-east coast in the neighbourhood of the mouth of the river

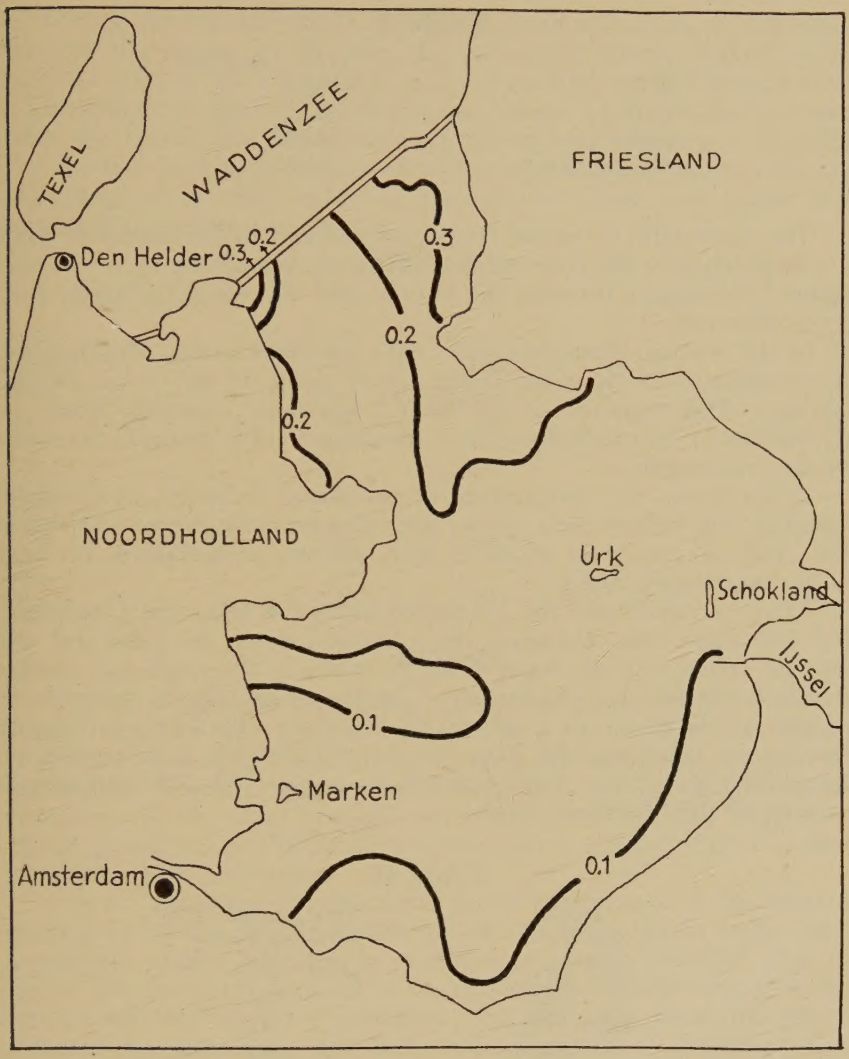

Fig. 2. Isohalines (Cl $^{0}/_{00}$) of the IJsselmeer, June 1939.

IJssel, an effluent of the Rhine, (2) the large central basin, filled with mesohaline water and (3) the northern boundary zone of a polyhaline character (see Fig. 1).

Normal values of some of the components of the mesohaline water in the central area are given in Table I. They have been computed from the figures of a dozen samples taken at different stations on June 4th, 1924.

Table I.

Cl	5170	mg./litre
SO_4	858·3	„
CaO	225·6	„
MgO	544·3	„
Total hardness	100·5	„

The mean salinity varied from year to year; in the month of June it was practically the same all over the area, amounting to 9—10 ‰. Marked differences between the bottom and the surface salinity were never observed.

In the northern boundary zone the Cl-content varied considerably, in consequence of the tidal action, from about 10 to 15 ‰ on the average. The isohaline of 10 ‰ Cl stretched from the coast at Medemblik in North Holland in a southward curve towards Stavoren on the Frisian side.

In the main, the temperature of the water followed, as could be expected, the temperature of the air. During winter-time the water was often frozen over, while in high summer temperatures of over 30°C. have been noticed.

After the enclosure, the Zuiderzee became a lake, the IJsselmeer, and has since been changing the composition of its water by the constant influx of fresh water from the rivers in the south-east corner, of which the IJssel is the largest. The following figures, taken from a paper of A. Massink and L. G. M. Baas Becking (Recueil des travaux chimiques des Pays-Bas, 53, 9/10, 1934), give an idea of the rapidity of dilution. Each figure is the mean of 10—11 simultaneous analyses of the IJsselmeer water.

Table II.

Month of examination	Total amount of milli-equivalents
1932 Oct.	about 134
„ Dec.	„ 100
1933 Febr.	„ 92
„ April	„ 85
„ June	„ 79
„ Aug.	„ 68
„ Nov.	„ 62
1934 Febr./March	„ 54
„ June	„ 51

In the beginning the decrease of salinity was rather rapid, but later the freshing process slackened.

The average Cl-content, computed from regular observations on a very large scale, during the period 1936—1939 is shown in the following table.

Owing to the unevitable supply of small quantities of sea water through the sluices in the dike the salinity is always highest in the northern part of the IJsselmeer. A small area of rather brackish water is also present in the very south-western corner, where mesohaline water from the North Sea Canal comes in through sluices near Amsterdam. For the rest the IJsselmeer nowadays has a weakly oligohaline character and along with the freshening process the flora and fauna have completely changed (see Fig. 2).

Table III.

Cl mg. per litre in	1936	1937	1938	1939
Febr.	390	—	—	175
March	—	165	175	—
April	—	—	—	165
May	340	145	180—195	—
June	340	—	—	160
July	—	160	220	170
August	300	175	—	—
Sept.	—	—	210	170
Oct.	295	190	—	—
Nov.	—	—	215	—
Dec.	240	190		

Biology.

The old Zuiderzee, containing chiefly mesohaline water which was largely supplied with nutritive substances from the rivers as well as from the towns and villages along its coast, offered excellent conditions for the development of plant and animal life, and showed the typical character of the true brackish-water associations. The number of species living in the Zuiderzee was not very great but the individuals were extremely numerous.

It is of importance to note, first, that in consequence of the incessant stirring up of the superficial bottom layers sessile plants were almost completely absent and strictly confined to certain localities near the coasts. On the sandy grounds in the northern boundary zone, however, *Zostera marina* was very common. On the other hand the phytoplankton was extremely rich and consisted chiefly of diatoms, among which *Thalassiosira baltica* and *Coscinodiscus biconicus* were by far the most abundant. Cyanophyceae were absent, Chlorophyceae very rare.

In the zooplankton only a few species of copepods occurred. The true mesohaline forms, viz., *Acartia bifilosa, Ac. tonsa* and *Eurytemora hirundoides*, were the predominant species, the first during spring-time, the second in summer and autumn, the last during the whole year. In the northern boundary zone *Centropages hamatus* was often met with in great numbers. Freshwater copepods, especially *Cyclops*, only appeared in very small numbers and particularly in the oligohaline south-eastern corner, together with a few freshwater Cladocera. *Podon polyphemoides* was occasionally introduced from the northern part,

rotifers were practically absent, with the exception of the typical mesohaline species *Synchaeta littoralis.*

The specific bottom fauna of the brackish water *sensu strictiori,* i.e., of the mesohaline zone, was well represented by several members of this community. Besides certain Foraminifera and nematodes the following were particularly abundant in the main basin.

Chaetopoda: *Peloscolex heterochaetus, Streblospio shrubsolei, Heteromastus filiformis, Nereis diversicolor;* Crustacea: *Cyprideis littoralis, Corophium volutator, C. lacustre, Leptocheirus pilosus, Gammarus zaddachi, Sphaeroma rugicauda;* Mollusca: *Mya arenaria, Cardium edule, Macoma baltica, Hydrobia stagnalis.*

The distribution of a few other genuine brackish-water species, such as *Pygospio elegans, Polydora redekei, Alkmaria romijni, Candona angulata, Cyprinotus salinus, Cypridopsis aculeata, Cyathura carinata, Jaera albifrons, Tergipes despectus* etc.[1]) was more localized.

Most of these animals and the above-named diatoms form a favourite food of fish at different stages, either larvae or full grown. Owing to the abundance of nutritious plankters and the high temperature of the water in the summer months the shallow basin was an ideal nursery for young fish.

The marketable fish of the Zuiderzee were the herring and anchovy, flounder, smelt and eel, the common shrimp (*Crangon vulgaris*) playing also an important rôle.

The herring belonged to a special spring-race of the North Sea and entered the Zuiderzee from March until July for spawning. The chief spawning grounds were situated on the sand banks near the western and southern coasts. Here the eggs were deposited on the stems and branches of hydroids, especially *Laomedea gelatinosa,* growing abundantly on these banks. The larvae and young fish fed chiefly on *Thalassiosira* and copepods and left their birthplace in the autumn for the North Sea. A small number came back after two years, but the majority of the ripe Zuiderzee herring consisted of three-year-old individuals.

The anchovy entered the Zuiderzee about one month later. It is worth noting that the first shoals made their appearance as a rule in the last decade of April, just in the period in which the temperature of the Zuiderzee became higher than that of the North Sea. As is well known, the number of individuals and consequently the catches of anchovy varied considerably from year to year (*vide* Table IV). Spawning took place in the northern funnel-shaped part of the area; the pelagic ellipsoid-shaped eggs were as a rule most numerous in June and July and developed under favourable circumstances in a little less than three days, at temperatures varying from 14 to 17°C. The newly hatched larvae reached, by drift and active migration, the central

[1]) I may draw the attention to the fact that most of these species, together with some others, less frequent, occur likewise in similar brackish localities of north-western Europe.

basin and grew rapidly during summer, reaching an average length of 9—10 cm. in the month of October. Then the young anchovies left the Zuiderzee, but the greatest part, about 80 per cent., came back again next spring as nearly ripe fish and spawned, being then one year old and having grown to an average length of about 15 cm. The remaining 20 per cent. consisted of 2-year- or exceptionally 3-year-old individuals. In cold summers most of the eggs died and larvae were rare; so it could be predicted that the next year's catch in the Zuiderzee would be a bad one. And thus it was the temperature of the water which in the first place caused the astonishing fluctuations of the catches.

The flounder was the third valuable fish of the old Zuiderzee. Enormous quantities of young bottom stages entered in early spring from the North Sea and swarmed all over the area, feeding in the first weeks chiefly on small Polychaetae, later almost exclusively on *Corophium* and *Nereis;* so the marketable fish were always in fine condition and very good eating. They stayed until ripeness approached and left the Zuiderzee as a rule at the age of three or four years; larger and older specimens, up to 10—12 years, however, were occasionally captured. Our marking experiments have proved that only a small percentage of our flounders re-entered the Zuiderzee after spawning. Most of them migrated from the spawning grounds in the neighbourhood of the Dutch coast in a southerly direction and were recaptured far from the places of liberation, even in the estuary of the Seine.

Two other fishes of economic importance were the common eel and the smelt. As usually in brackish coastal waters male eels prevailed, the females migrating for the greatest part into fresh water. The smelt was caught chiefly in the colder seasons and in the less brackish part of the basin; in hard winters it was caught with stake-nets under the ice. For spawning purposes it ascended the IJssel and other, smaller, rivers.

Full-grown plaice and dab occurred in the more saline part of the northern area, but young individuals of the first-named were not rarely met with in the south-western corner of the basin. Other marketable fish as sturgeon, sprat, salmon, sea-trout, were caught only casually. *Gobius minutus* and *Gasterosteus aculeatus* were numerous, but freshwater fish were almost entirely absent.

A valuable object was also the common shrimp, which was fished in summer and was highly esteemed for its excellent flavour. The molluscs occurring in the southern part of the Zuiderzee never reached a marketable size; among those of the northern boundary zone the only one of importance was *Mytilus edulis,* the mussel, which could not thrive in the brackish water of the main basin.

As will be seen from Table IV the herring was by far the most important fish; the catches of anchovies show the remarkable fluctuations mentioned before. In the top year, 1926, over three million kilogrammes were landed.

Soon after the closure of the Zuiderzee the flora and fauna of the enclosed area totally changed. The typical mesohaline copepods *Acartia tonsa* and *Eurytemora hirundoides* disappeared in the year 1934; they are now replaced by oligohaline species, chiefly *Eurytemora affinis* and *Cyclops vernalis americanus*, which nowadays together with *Daphne longispina* and *Leptodora kindti* are the predominating planktonic crustacea. Similarly the old bottom fauna died out. The Polychaetae are for the greater part replaced by freshwater Oligochaetae. Some very euryhaline species such as *Cyprideis littoralis* among the ostracods, and *Nereis diversicolor* resisted for many years the decrease of salinity but finally they too had to give up the struggle for life. The small brackish-water forms of *Cardium, Macoma* and *Mya* are left only as empty shells, but the little oligohaline snail, *Hydrobia jenkinsi*, is now very common. The remarkable crab, *Heteropanope tridentata*, has spread out from the west coast over a wide area and in the IJsselmeer is much more numerous than it was in the Zuiderzee. The mesohaline diatoms showed a marked decrease since 1934 and have now completely disappeared; they are replaced by the common planktic freshwater species, such as *Asterionella gracillima* and *Diatoma elongatum*. Cyanophyceae, which were practically absent in the Zuiderzee, are now flourishing, especially *Microcystis aeruginosa*.

Of course the fish population has undergone similar considerable changes, as will be seen from the Table IV below. This table contains the annual catches of the principal food fishes in 1000 kg. and the total value in 1000 guilders in the 7-year period before and the 7-year period since the closure, for the total enclosed area.

Table IV.

Quantity (in 1000 kg.) and total value (in 1000 guilders) of fish caught in the IJsselmeer in the seven-year periods before and after the enclosure.

Year	Herring	Anchovy	Flounder	Eel	Smelt	Garfish	Shrimp	Total value
1925	8,987	1,384	1,067	756	1,478	6	1,910	3,612
1926	6,263	3,326	709	714	802	23	1,588	3,499
1927	9,643	882	711	602	711	33	2,541	2,537
1928	12,387	139	1,008	694	1,273	22	2,117	2,507
1929	10,621	397	1,686	858	752	4	2,048	2,629
1930	11,246	5,428	3,647	838	1,285	2	2,313	4,808
1931	12,106	3,578	2,321	941	1,349	3	1,588	3,094
1932	9,985	378	1,273	1,048	476	9	589	1,788
1933	12	—	1,265	2,125	337	—	50	1,470
1934	—	—	1,124	2,688	447	—	—	1,662
1935	0·1	—	232	1,970	317	—	—	1,068
1936	—	—	48	2,405	271	—	—	1,091*
1937	—	—	43	3,595	130	—	—	1,315*
1938	—	—	25	2,588	209	—	—	1.285*

* Value of considerable quantities of freshwater fish, especially pike-perch, included.

The figures show clearly the sudden diminution in quantity and early disappearance of the most important fishes after 1932, the year of the closure. In that year the spring herring could still enter in fair quantities and even the first shoals of anchovies came in all right. But in the following year the catch of herring was seriously reduced and the anchovy was entirely absent. In 1934 no herring was caught, in the next year again a few, but then no more.

It was hoped that the herring as well as the anchovy in future would spawn in the unenclosed northern part of the Zuiderzee, the so-called "Waddenzee", but obviously the conditions here are not favourable, as since February 1934 no young herrings were observed in this region. On the contrary, extensive investigations on the larvae occurring in this part of our coastal waters proved that they belonged exclusively to the Bank herring of the North Sea. Of the anchovy here only newly hatched larvae were captured; later stages were absent. Probably they cannot develop, as the temperature of the sea water in this area is too low.

Among the other marketable fishes the flounder shows a more gradual decrease, the stock to a certain extent being replenished by young bottom stages, occasionally slipping through the sluices and growing up so long as there was food enough. During the freshening process, however, their chief food supplies, such as *Corophium volutator* and *Nereis*, were more and more suppressed; so the number of flounders growing up to a marketable size was strongly reduced.

To a less degree, the same holds good for the smelt. As this fish spawns in fresh water its migrations are not impeded by the closure but here again the lack of the old mesohaline food-animals seems to account for the decrease. Gar-fish (*Belone belone*) entering in spring from the North Sea for spawning in the northern boundary zone soon disappeared and the same is the case with the common shrimp, which was born in the coastal waters and used to penetrate into the southernmost parts of the Zuiderzee for feeding.

A different picture is shown by the eel. Large quantities of elvers are allowed to come in at the sluices and in this way the stock is periodically supplemented. Owing to the freshening of the IJsselmeer the fish need no longer move away from the brackish zone for rivers and inland waters. So they stay nowadays where they are and are caught in larger quantities than before. This rather unexpected outcome of the enclosure has given rise to complaints about the inland fisheries in certain districts. The average size of the eel during the brackish-water period was larger than in the years after the closure.

Nowadays the pike-perch, *Stizostedium lucioperca (= Lucioperca sandra)*, is the most valuable freshwater fish of the IJsselmeer. It arrived from Germany in Holland in 1888 and has since spread through our rivers and canals all over the country. As smelt forms its favourite food, it was to be expected that it should thrive very well in the IJsselmeer. Recent observations have moreover proved that spawning

takes place on a large scale every year. How rapidly the stock has increased is shown in Table V.

Table V.

Quantity of Pike-perch, *Stizostedium lucioperca*, caught in the IJsselmeer.

Year:	1933	1934	1935	1936	1937	1938
Kg.:	111	338	1,552	8,373	71,174	125,082

In the years before the enclosure the fish was only occasionally met with.

Similarly another fish, viz., the pope or ruffe, *Acerina cernua*, which seldom occurred in the old Zuiderzee, has propagated enormously in the IJsselmeer. This little Percoid, having no value as food for man, is used as food for ducks and sometimes eaten by pike-perch. Consequently it does not appear in our fishery statistics, but on a rough estimation the total quantity landed in 1938 amounts to at least 5 millions of kilogrammes. As the pope feeds chiefly on worms and Chironomid larvae it is considered as a serious food-competitor of the eel.

Conclusions.

1. In consequence of the closure of the Zuiderzee, this formerly mesohaline estuary has been transformed into an oligohaline, nearly fresh lake.
2. The plankton and the bottom fauna changed rapidly and the old brackish-water species have been replaced by new ones, imported from inland waters.
3. Of the plankters the most valuable species have disappeared; on the other hand only a few of the newcomers have any value as fish food.
4. The principal fishes have either completely disappeared (herring, anchovy), or their stock has severely shrunk (flounder).
5. Eel and smelt are left and, together with the pike-perch and some other freshwater fish, form the chief objects of the fisheries of to-day.
6. The total productivity of the whole area has perceptibly decreased, the mean yearly yield being reduced from 3,241,000 guilders in the period 1925/31 to 1,383,000 guilders in the period 1932/38. This means a loss of nearly 60 per cent. or about 2 millions of guilders. The damage suffered by the fishermen, has, however, to a certain extent been compensated by grants from the Government.

Analysis of Evidence relating to Eddy Diffusion Processes at Mid-Depths in the Eastern Caribbean.

By

A. E. Parr,

Bingham Oceanographic Laboratory.

DURING the early months of 1933 the research ship "Atlantis" made a first hydrographic survey of the Caribbean under the joint sponsorship of the Woods Hole Oceanographic Institution and the Bingham Oceanographic Laboratory of Yale University, with the author in charge. Certain features in the distribution of the water masses led to an interest in the problems of mixing processes. A qualitative statement of a principle concerning the relationship between vertical stability and lateral diffusion was made (Parr 1936) with certain Caribbean distribution patterns referred to as a possible illustration of a situation which may have been partly governed by this principle, but with the explicit statement that the data could not be classified as evidence (Parr 1936, p. 312), and the implied conclusion that the data were inadequate for quantitative treatment, which would have to await more complete observations from a subsequent expedition, then contemplated.

This second expedition of the "Atlantis" to the Eastern Caribbean took place under the same sponsorship in the early months of 1937. In spite of the more detailed observations available from this second cruise, the author was again reluctantly forced to the conclusion that the data and the complexity of conditions in the Caribbean were such that it seemed advisable to give up the attempt to extract definitive evidence and quantitative values relating to diffusion processes from observations in this region (Parr 1938, pp. 1 and 28), while valuable information on other aspects of Caribbean hydrography was of course added to our knowledge also by this second cruise. The qualms felt in regard to the inadequacy of the data for the particular purpose of diffusion studies relate especially to conditions at mid-depths near salinity minimum, but also to a greater or lesser extent to all other levels.

When only two selected profiles from the earlier (1933) series of data alone have subsequently been made the basis for quantitative calculations of absolute diffusion values by Seiwell (1938[1])), while the present writer still retains his absolute conviction that none of the available data are adequate for such calculations, the obligation to investigate the justification of this conviction can scarcely be avoided, particularly in view of the fact that the writer is directly responsible for the original data involved.

Since a complete investigation of all the available records from the Caribbean would involve much more labour and tedious discussion than the situation may reasonably warrant, we shall confine our attention to the data from the two Eastern Caribbean profiles selected for treatment by Seiwell. Since, furthermore, our main concern over the inadequacy of the data refers to conditions at mid-depths, we shall also limit our analysis to the layers adjacent to the salinity minimum surface.

Seiwell's analysis of diffusion processes rests entirely upon the assumption that conditions with reference to turbulence are approximately the same in the oxygen minimum and the salinity minimum surfaces, an assumption which in itself seems entirely unacceptable to the present writer. As pointed out elsewhere (Parr 1938), such reasonably adequate observations as we have for conditions near the salinity minimum all indicate the existence of definite secondary maximum of vertical stability at this surface. Oxygen minimum is, on the other hand, generally closely associated with the absolute stability minimum above the minimum salinity surface. In our best example (Station 1512, see Parr, 1938, Fig. 23 p. 26. Oxygen minimum occurs at about 650—700 m. depth) the indicated vertical stability around oxygen minimum is less than one-fourth of that around salinity minimum. To base any calculations on the assumption that the equations for the oxygen minimum and the salinity minimum surfaces, when combined, contain only two unknown factors (t and A) instead of four (t_{O_2}, A_{O_2}, and $t_{sal.}$, $A_{sal.}$) is therefore scarcely permissible to begin with.

In carrying out the analysis Seiwell further introduces two rather striking inconsistencies, namely: 1) by the application of superficially different methods of mathematical procedure to the study of each of the two surfaces concerned; and 2) by the use of the averages for entire profiles in one instance (O_2 minimum) but only the individual data from a single pair of stations in the other.

When Jacobsen's formula for the eddy-diffusion coefficient (A):

$$A = \frac{\varrho}{8t} S^2 \tag{1}$$

is applied to the salinity minimum layer; and Schmidt's formula

[1]) Also incorporated in H. R. Seiwell: Application of the Distribution of Oxygen to the Physical Oceanography of the Caribbean Sea Region. Pap. Phys. Oceanogr. Met. Mass. Inst. Techn. Woods Hole Oceanogr. Inst. Vol. VI, No. 1. September 1938. Pp. 45—50.

$$A = \varrho \frac{\frac{\Delta \alpha}{\Delta t}}{\frac{\delta^2 \alpha}{\delta z^2}} \tag{2}$$

is used in the analysis of the oxygen minimum layer, it carries the implication that these two formulae are basically different from each other, so that the values obtained should not only be derived from different sets of original data but also by mathematically independent methods of analysis.

But it is obvious from its derivation and from the premises for its application that Jacobsen's equation (1) only represents a highly useful and valuable practical approach to the determination of vertical mixing coefficients in first approximation, but that it is not in logical contents distinct from Schmidt's more precise expression (2). In the application of the method Jacobsen (1927, p. 410) assumes that the T—S correlation curve through the layer investigated forms a fragment of a true circle and that equal distances along this portion of the curve represent equal depth intervals. But, on these premises, the form of the T—S curve over the portion concerned is uniquely determined by the vertical distribution of *either* variable *alone.* That is, if we wish to compare station curves so construed as to consist of fragments of circles, within each of which equal distances represent equal depth intervals, using rectilinear scales for the values of the variable, we can draw such curves separately for either salinity or temperature, on the basis of the vertical distributions of each of these properties, *which contain all the information required for the determination of curves of this description.* Jacobsen's equation could then be applied to the comparison of station curves, so construed, for either variable alone. Such a procedure might actually at times prove a practical extension of Jacobsen's very useful method. But in general practice his own limitation of its use to a consideration of T—S correlation curves only, and not to separate curves for each variable drawn to fulfill his premises, is greatly to be recommended. This, however, actually means only that the use of his method should generally be limited to the singularities in which the circular fragments of the curves for each variable can be made to coincide by a suitable selection of linear scales for the two variables oriented at 90° to each other, so that the coincident curve also comes to be the actual correlation curve for the natural occurrence of the two properties. By the limitation of the method to these singularities one will be completely safeguarded against any confusion of the hydrographic homologies between the circular fragments in the curves which might be construed for the separate variables as observed at different stations. But beyond its practical convenience and this safeguard required by the method's own character, Jacobsen's method contains no *consideratum* which is not also, and more fully, expressed in Schmidt's equation.

There is thus no logical reason for the alternate use of equations

(1) and (2), and nothing is gained by this procedure except a slight confusion of the issue, notably as it affects the obviousness of the degree to which all values obtained are entirely dependent upon one single and very hazardous assumption, namely, that the *specific* rate of oxygen consumption over the short distance (445 km.) between two profiles *inside the Caribbean* should be the same as the *average* rate of oxygen consumption in the oxygen-poor layer previously calculated by S e i w e l l for the tropical *mid-Atlantic.* If the rate of change of a nonconservative property due to other factors than diffusion is known, it does become possible to calculate diffusion coefficients by combining observations on this property with simultaneous observations on a conservative element, as proposed by S e i w e l l. If, for instance, the change in salinity is denoted by $S_2—S_1$, we have

$$S_2 - S_1 = A\frac{\delta^2 s}{\delta z^2} \cdot t \tag{3}$$

which gives

$$A \cdot t = \frac{S_2 - S_1}{\frac{\delta^2 s}{\delta z^2}} \tag{4}$$

Letting $O_2—O_1$ express the total change in oxygen content, and c the time rate of oxygen consumption per unit volume, we also have

$$O_2 - O_1 = A\frac{\delta^2 O}{\delta z^2} \cdot t - ct \tag{5}$$

Substituting according to (4) and solving for t this gives

$$t = \frac{1}{c}\left[(S_2 - S_1) - \frac{\frac{\delta^2 O}{\delta z^2}}{\frac{\delta^2 s}{\delta z^2}} \cdot (O_2 - O_1)\right] \tag{6}$$

From (6) it becomes obvious how the absolute values for A and t calculated by S e i w e l l for mid-depths in the Caribbean are entirely dependent upon the use of a value of c which has not been derived from Caribbean data at all, in addition to their being also dependent upon the even more debatable assumption of identical eddy diffusion coefficients around oxygen minimum and around salinity minimum.

The second inconsistency in S e i w e l l's analysis, already referred to, is found in the use of the *average* vertical oxygen curve for each *entire profile* for analysis of the oxygen minimum layer by S c h m i d t's equation (2), while J a c o b s e n's equation (1) is only applied to the comparison of the T—S curves from one selected, approximately mid-point station, for each profile, with the comment that "it may be accepted that the relative functional relationships of temperature and salinity in profiles I and II, in the vicinity of the salinity minimum, are represented with sufficient accuracy, by those for stations 1499 and 1510" (S e i w e l l 1938, p. 157). When we examine the station

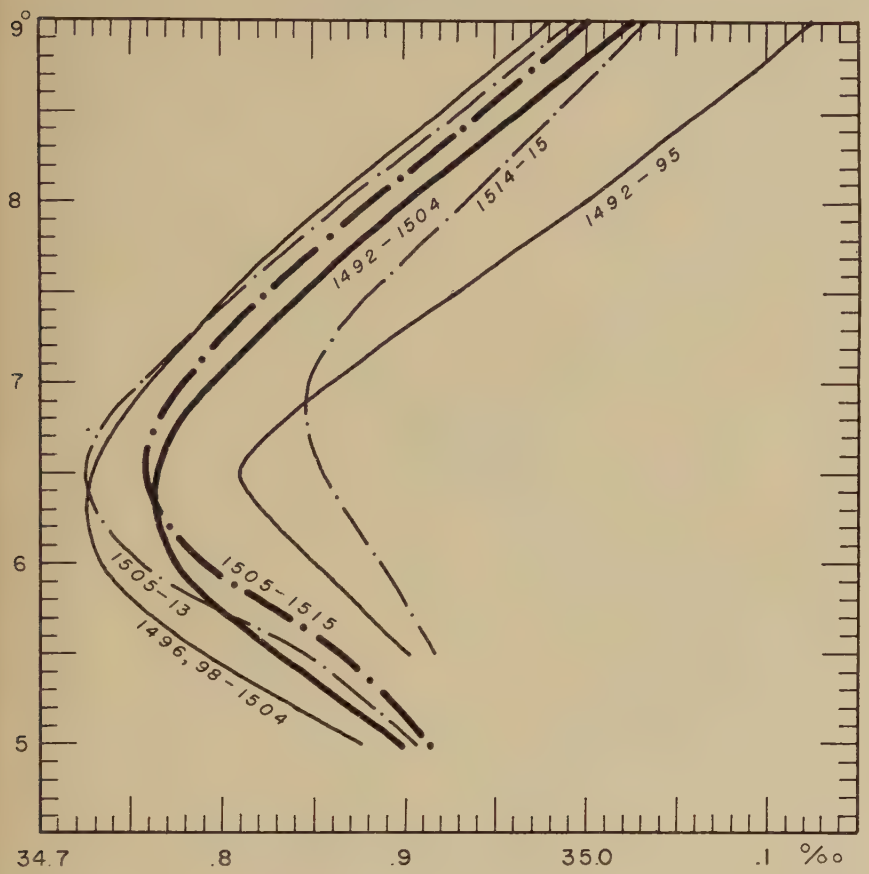

Figure 1. Average Temperature-Salinity correlation curves around salinity minimum. *Solid lines:* First (eastern) profile. 1) *Heavy:* Average curve for entire profile. 2) *Light:* Average curves for northern (1492—95) and for remaining (1496, 1498—1504) stations in first profile. *Dot and Dash:* Second (western) profile. a) *Heavy:* Average curve for entire profile. b) *Light:* Average curves for northern (1514—15) and for remaining (1505—13) stations in second profile.

records, we find that an application of Jacobsen's method to the *average* T—S curves for each profile, consistent with the application of Schmidt's method to the average oxygen curves, *is actually an utter impossibility* for the simple reason that these average curves around salinity minimum[1]) show no significant difference at all between the two profiles, as illustrated in Figure 1. The only conclusion which could be drawn from a consistent application of both equations to *true profile averages* would therefore be the patently unsatisfactory

[1]) Calculated from the intercepts between given temperature coordinates (9°, 8°, 7·5°, 7°, 6·5°, 6°, 5·5°, 5°) and the individual station curves as shown in Figures 2 and 3.

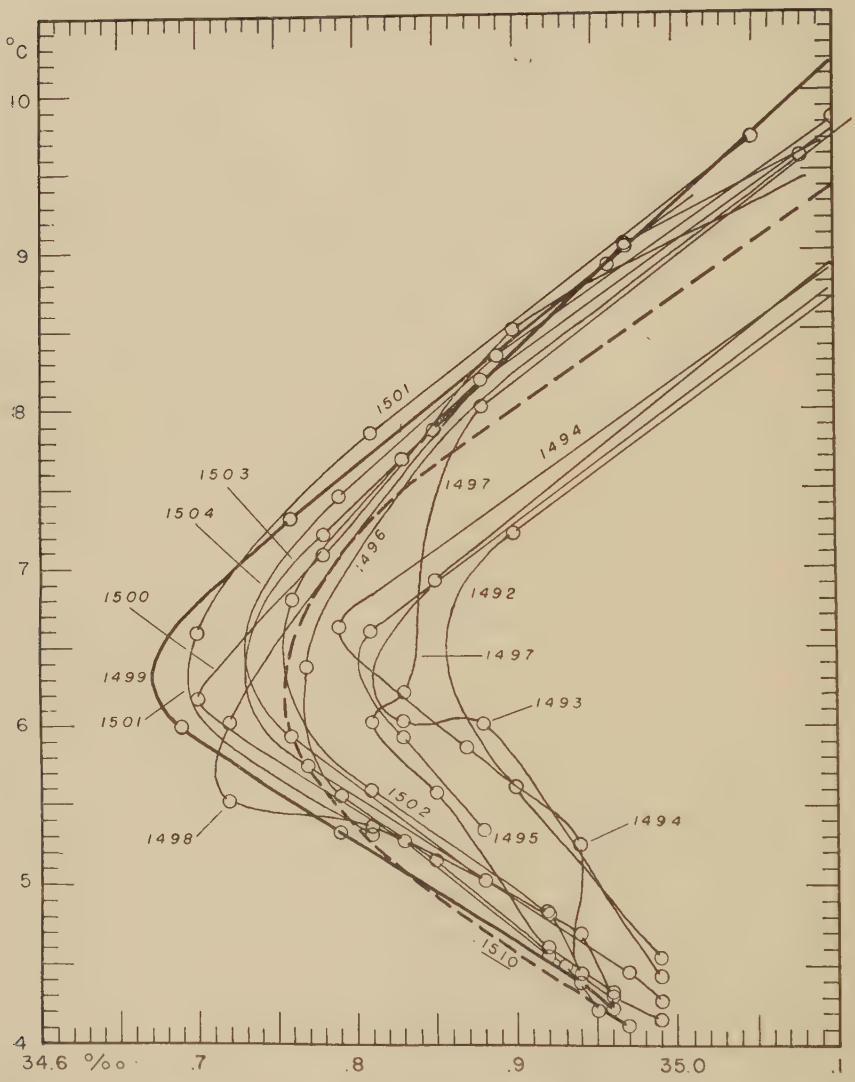

Figure 2. Temperature-Salinity correlation curves for individual stations in first (eastern) profile, Stations 1492—1504. Curve for Station 1499 heavier than others. Curve for Station 1510 entered in broken line for comparison.

one that while appreciable vertical mixing seems to have occurred around oxygen minimum, none is indicated at salinity minimum. On the basis of this picture of the virtual identity of the average T—S curves, the acceptance of individual stations, showing great differences, as representatives of each separate profile is obviously not permissible.

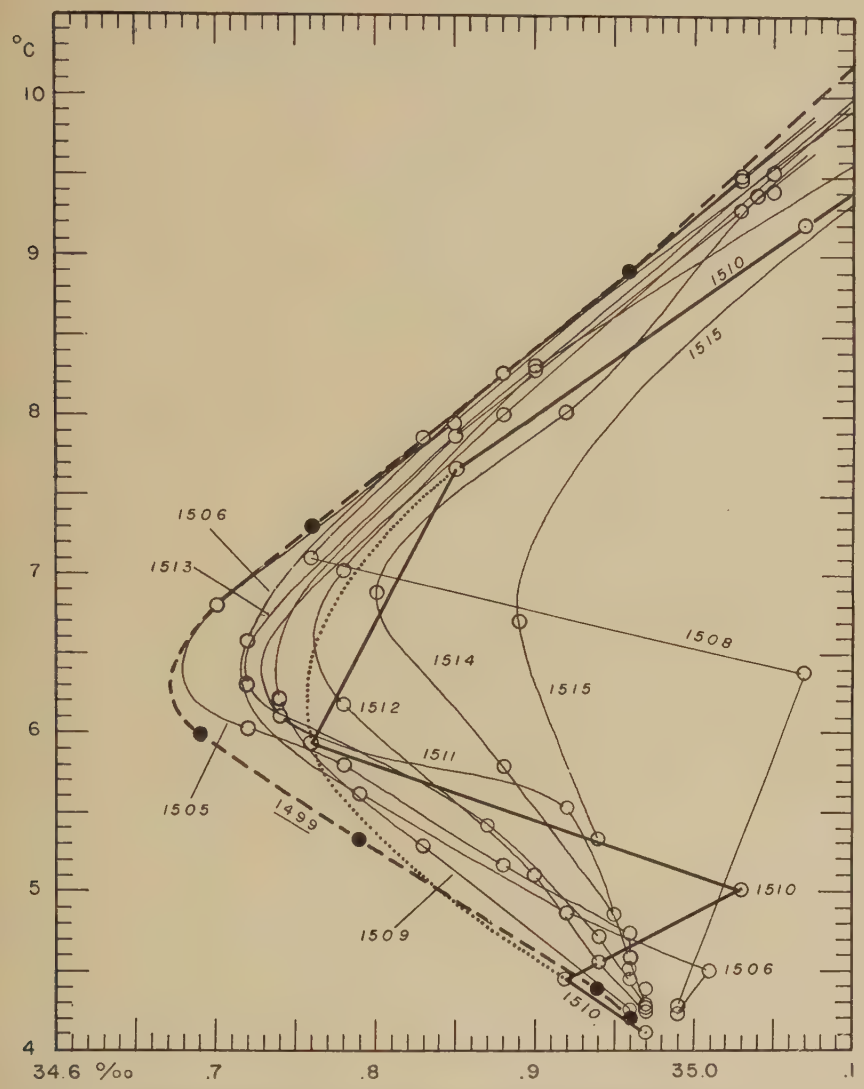

Figure 3. Temperature-Salinity correlation curves for individual stations in second (western) profile. Curve for Station 1510 heavier than others, with interpolated parts dotted. Curve for Station 1499 from first profile entered in broken line for comparison.

The reason for the present writer's earlier rejection of these data for calculations similar to those since carried out by Seiwell lay mainly in this very fact that the hydrography of the region seemed too complex to make averages usable, while precise trajectories were not well enough known to permit of comparison between individual stations from separate profiles.

Nevertheless, the question of whether comparisons between individual stations or between averages for relatively homogeneous fractions of the profiles are possible or not might be looked into further.

From Figure 3 we notice that the records for stations 1508 and 1510 contain such obvious errors that they should both be disqualified for consideration in relation to conditions obtaining around salinity minimum. When station 1510 is used by Seiwell to represent profile II, this can only have been done by disregarding the patently erroneous salinity record of 35·03 ‰ at temperature 5·01° C., and by joining the lowest salinity record (34·76 ‰ at 5·94° C.) to the second observation below (34·92 ‰ at 4·45° C.) in some such manner as that suggested by the dotted curve. But this leaves a depth interval of 399 m. between the upper reading used for salinity minimum at St. 1510 and the next usable reading below, and the uncertainty introduced is such that it is scarcely permissible to use the curve thus obtained as a basis for quantitative calculations.

In the averages here presented both stations 1508 and 1510 have been discarded as unreliable for temperatures lower than 7·5° C., and station 1507 has likewise had to de discarded entirely for the T—S range covered by our illustrations. When we further consider that the curves as presented have already in several instances been corrected for presumably identifiable transpositions in the station records, the second major reason why the present writer felt forced to abandon the attempt to make quantitative calculations of mixing processes on the basis of these data should become abundantly apparent.

In Figure 3 it is also evident that the dotted curve for station 1510, far from being representative of the average conditions within the second profile, actually falls within the *upper* range of its salinity minimum values. Conversely we notice from Figure 2 that station 1499, selected by Seiwell as representative of this profile (I) actually represents the extreme case of *low* minimum salinity values within this section. Used as examples of their respective profiles, the two stations (1499 and 1510) selected by Seiwell must give a grossly exaggerated, nearly maximal, value for S in equation (1) which cannot in any legitimate manner be combined with the results obtained from the application of equation (2) to the *average* oxygen curve for each *entire* profile.

If we want to compare individual stations in the two profiles, it is obvious that they must be paired for comparison in relation to the most likely trajectories between the sections. If the minimum salinity distribution (see Parr 1937, Figure 42, p. 59) is any indication of the general direction of flow within the salinity minimum layer, it is obvious that the curve for the central station 1499 in the easterly profile (I) should be compared with that for the most southern station, 1505, in the second profile (II). This comparison is shown in Figure 3, and again we find no clear evidence of vertical mixing around salinity minimum. In fact, the minimum *recorded* salinities at station 1499

(34·69 ‰) and at station 1505 (34·70 ‰) differ by less than the usual allowance for practical average error of determination.

If we want to make comparisons between pairs of stations regardless of their positions, it is evident from Figure 2, in which the broken line indicates the curve for station 1510 from the second profile, that we may arbitrarily choose our pairs so as to indicate mixing progressing from west to east just as well as from east to west according to our choice.

If finally we want to consider groups of stations from each profile, it is obvious that the stations of the first profile (Figure 2) fall into two fairly well-defined groups, one consisting of the northern stations (1492—1495) and one comprising the stations to the south of these (1496, 1498—1504). Of these, the northern group shows high minimum salinities, and high salinities throughout the range covered by our figure, while the southern group shows low salinities throughout. One single curve (station 1497) crosses over from one group to the other and has been omitted in the calculation of the group averages. In the second profile we quite similarly find the two stations farthest to the north (1514 and 1515) deviating conspicuously from the other stations by their higher salinities. In Figure 1 the average curves for the northern and southern sections of each profile have also been entered (in lighter lines) for comparison. Again we find that the average curves for the southern sections give absolutely no clear and distinct evidence of any vertical mixing around salinity minimum having occurred between the two profiles; and such differences as there are between the averages for the northernmost parts of the profiles are not capable of any simple interpretation, and are also not of very great significance due to the comparatively few observations on which the northern averages, particularly for the second profile (two stations only), are based.

It thus appears that neither the average T—S curves for the entire profile, nor average curves for apparently natural groups of stations within each profile, give any significant evidence at all of vertical mixing around salinity minimum, and any figures arrived at as presumably representative of *average* changes between the two profiles must be rejected as invalid.

Since, on the other hand, the conclusion that no clear evidence of any vertical mixing at all can be obtained from average curves seems definitely unsatisfactory, we might call attention again to the statement made above, to the effect that by arbitrarily selecting individual stations, one from each profile, for comparison we may find apparent indication of vertical mixing progressing in either horizontal direction we might wish, from east to west or *vice versa*. Perhaps the combination of these two circumstances, constant averages and highly variable individual station curves, might be taken as a vague suggestion that the confusing fact of the situation may be the existence of horizontal eddy movements or counter currents on such large scale that the transport from one profile to another may actually have been variable

in its main direction. This would be quite in accordance with the lack of variation in the averages for the entire profiles at the same time as it would permit of actual vertical mixing having occurred along all true trajectories. The suggestion is purely hypothetical, however, and not capable of direct proof on the basis of the data now available.

If, finally, a still vaguer suggestion should be permissible, one might point to the consistent tendency both for the average curves for the northern and southern groups of stations in each profile, and of the average curves for all stations, to intercept each other at salinity minimum, and inquire whether this might not be considered faintly indicative of the possibility that the salinity minimum surface might also perhaps, on the average, be a surface of discontinuity with reference to horizontal motion.

When the absolute values for t have to be discarded, the absolute value for the vertical diffusion coefficient, A, at mid-depths derived by Seiwell (1938) must also be abandoned, since the two are entirely interdependent.

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Daily Temperature Variations in the Western North Atlantic.

By

H. R. Seiwell.[1][2]

IN the summers of 1936, 1937, and 1938 continuous measurements of temperature (and other characteristics) at fixed depths (between surface and 1200—1300 metres), over intervals of 57 to 314 hours, have shown that disturbances of the water column cause significant short period changes in the observed state of the sea. Thus, in general, projections of oceanographic characteristics, based on isolated series of samplings, will not represent average conditions (for the observation period) unless observational data is controlled by ascertaining orbits of time variation for estimation of significance of calculated orbits of space variation.

Station Data.

Stations for measurement of time variations of temperature (and other oceanographic characteristics) were located in the western Atlantic basin between Bermuda and the Gulf Stream system, where for considerable distances, horizontal gradients of oceanographic properties are small (in projected oceanographic sections the isolines maintain relatively level positions), a condition necessary because the ship was not anchored. During operation, frequent observations of ship's drift (and favourable weather) enabled samplings generally to be made within a radius of 2—3 miles (in no case exceeding 5 miles) from the mean station positions tabulated in Table 1. Mean geographic positions of stations 2887 and 3091 are nearly identical, both being located about 110 miles north-

[1]) Assistance for reduction of these observations was supported by a grant from the Penrose Fund of the American Philosophical Society.

[2]) Contribution No. 227 from the Woods Hole Oceanographic Institution.

Table 1.

Station	λ	φ	Measured depth	Duration of sampling 60° time	Number samplings
2639	66°25′W	35°07′N	5130	9^h 57′ July 9 — 17^h 07′ July 13, 1936	24
2886	65°59′W	32°19′N	4830	23^h 46′ June 16 — 08^h 28′ June 19, 1937	50
2887	65°56′W	34°01′N	5216	23^h 16′ June 19 — 13^h 34′ June 22, 1937	41
				7^h 57′ June 24 — 08^h 24′ June 28, 1937	72
3091	65°54′W	34°02′N	5133	12^h 21′ June 16 — 14^h 22′ June 29, 1938	194

west of Bermuda; station 2886 (about 100 miles to the south) is approximately 60 miles west of Bermuda. The present discussion concerns only these three stations; results from station 2639 having been discussed previously[3]).

To reduce observations for analysis, individual temperature depth curves for each sampling were scaled both for depths of significant isotherms and for temperature at standard depths, the scaled items being consolidated into averages, or used individually as required. The density distributions at each station were determined by combining average temperatures at standard depths and average depths of standard isotherms with salinity values scaled from temperature salinity relationships.

Vertical Displacements of Isotherms.

To specify vertical displacements at particular depths in the water column reference is made to various isotherms (average depths tabulated in Table 2), the apparent changes in position of which (in the western Sargasso Sea) may be considered as resulting from vertical oscillations of the water particles, a circumstance deduced because of the small horizontal isothermal gradients[4]). Certain errors affecting the items of each sampling, due to the slow drift of the ship and to the eddying motion of the water, are largely eliminated by averaging.

Although ranges of vertical displacements of isotherms vary from day to day (Table 2) a definite relationship to the vertical density distribution ($\Delta\sigma_t/\Delta Z$) always exists. Thus, at stations 2887 (Fig. 1) and 3091 (Fig. 2) magnitudes of vertical displacements, at a maximum where the water is least stable (to depths of 1200—1300 m.; $\Delta\sigma_t/\Delta Z =$ approximately 2×10^{-4}), are suppressed with increasing stratification.

[3]) See "Short period vertical oscillations in the western basin of the North Atlantic." Papers in Physical Oceanography and Meteorology. Vol. V, No. 2, 1937.

[4]) Maximum gradient of 10° isotherm: 1.33 metres per kilometre; and of 17° isotherm: 1.00 metres per kilometre; see footnote 2.

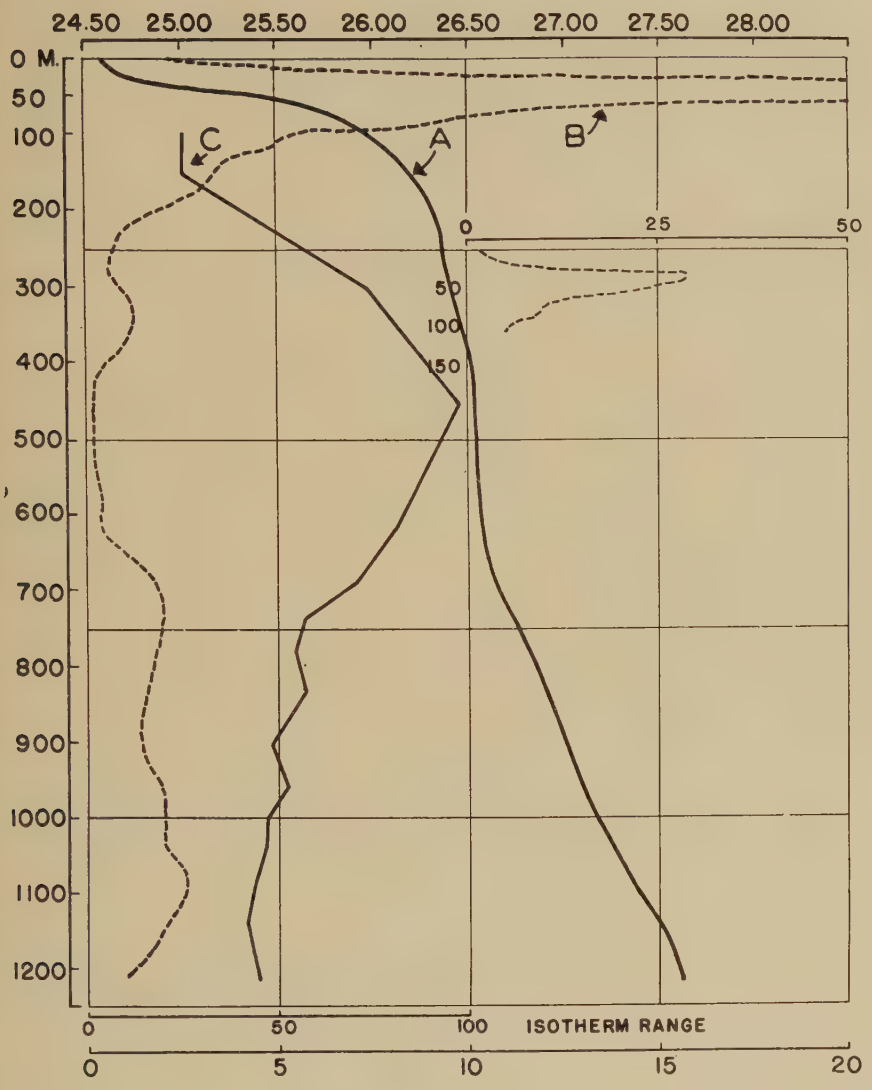

Fig. 1. A = average vertical distribution of density, σ_t, (top scale); B = average vertical variation of density, $\Delta\sigma_t/\Delta Z \times 10^3$ (lower scale); C = average vertical displacement ranges of isotherms (20°—6°; Table 2) for 6 days, Station 2887.

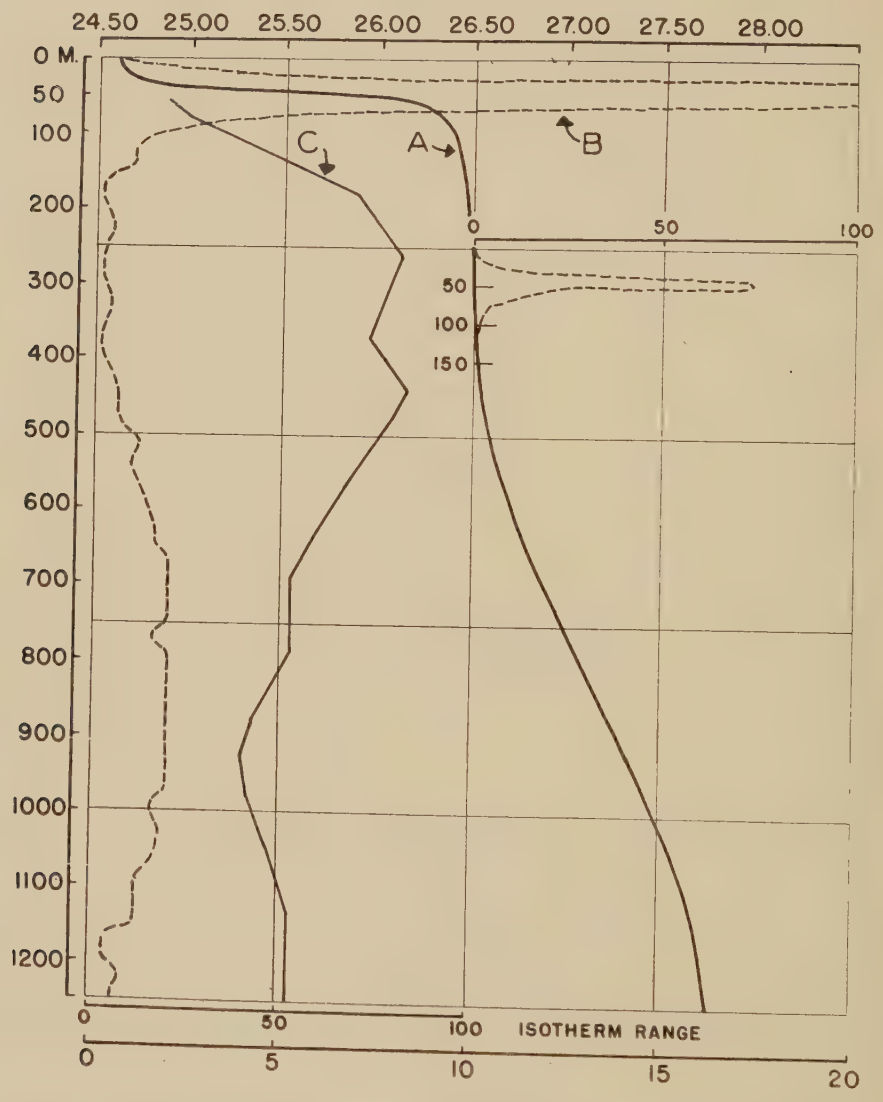

Fig. 2. A = average vertical distribution of density, σ_t, (top scale); B = average vertical variation of density, $\Delta\sigma_t/\Delta Z \times 10^3$ (lower scale); C = average vertical displacement ranges of isotherms (20°—5°; Table 2) for 13 days, Station 3091.

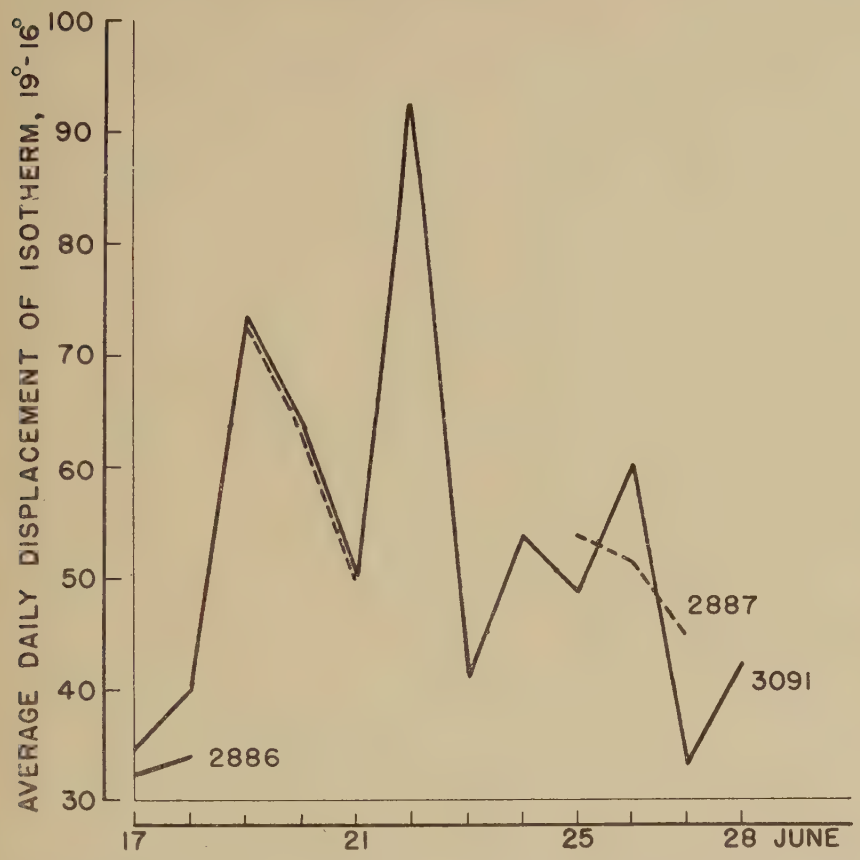

Fig. 3. Average daily vertical displacements of all unit isotherms between 19° and 6° for Stations 2886 (2 days) and 2887 (6 days) in 1937 and Station 3091 (13 days) in 1938 (see Table 1).

In this least stratified water, between 17° and 18° isotherms[5]), average daily vertical displacements at station 2887 were 81 to 97 m. and at station 3091, 73 to 83 m.; in the intermediately stratified deep water ($\Delta\sigma_t/\Delta Z = 2{\cdot}6 \times 10^{-3}$), average daily ranges of isotherms (15°—6°) decreased to 42—57 m. at station 2887 and to 40—59 m. at station 3091; and in the strongly stratified surface layer ($\Delta\sigma_t/\Delta Z = 74 \times 10^{-3}$)

[5]) At both stations the least stratified water was bounded by the 17° and 18° isotherms, and although observations were made at identical dates on successive years (Table 1) their average depths differed respectively by 121 and 142 metres, thus:

		Depth	$\frac{\Delta\sigma_t}{\Delta Z} \times 10^3$	σ_t
Station 2887	18°	300	0·2—1·2	26·41
	17°	618		26·57
Station 3091	18°	179	0·2—0·6	26·46
	17°	476		26·56

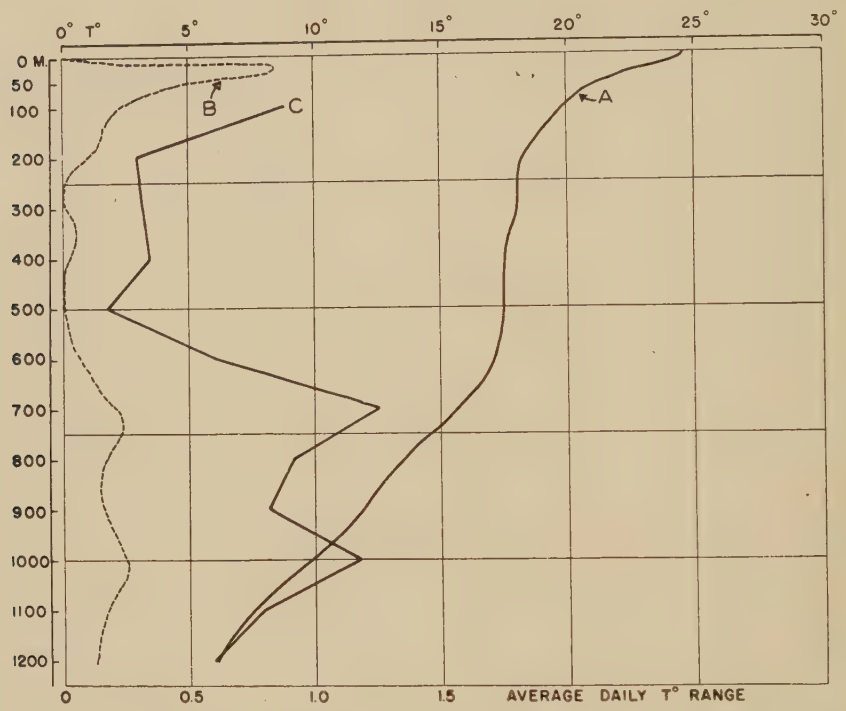

Fig. 4. A = average vertical temperature distribution (top scale); B = average vertical variation of temperature, $\Delta T°/\Delta Z \times 10^2$ (top scale); C = average daily temperature ranges at standard depths (lower scale; Table 5) for 6 days at Station 2887.

average daily ranges of isotherms (20° and 19°) were reduced to 19—26 m. (Table 2).

The occurrence of large day-by-day variations in magnitude of vertical displacements of identical isotherms is brought out by comparison of minimum and maximum daily ranges[6]) for 5 days at station 2887 and 12 days at station 3091 (Table 2). Likewise, day-by-day variations in average daily vertical displacements for all unit isotherms between 19° and 6°, at station 3091 (Fig. 3) during 12 days, show that the water column was disturbed least on June 27 and most on June 22, the average vertical displacements on the latter date being nearly three times that on the former.

Total changes in depths of isotherms (20°—6°) in the western North Atlantic (Table 3) during 5 consecutive days at station 2887 and 12 consecutive days at station 3091, far exceed maximum displacements recorded for any individual day (Table 2); at the former station, total displacements up to 165 m. occurred in the least stable water (between

6) In this respect, the computed daily ranges, being subjected to randomness of the observations, are not for any one case an accurate basis for comparison; the average range, used above, is a better statistic for characterization of the data.

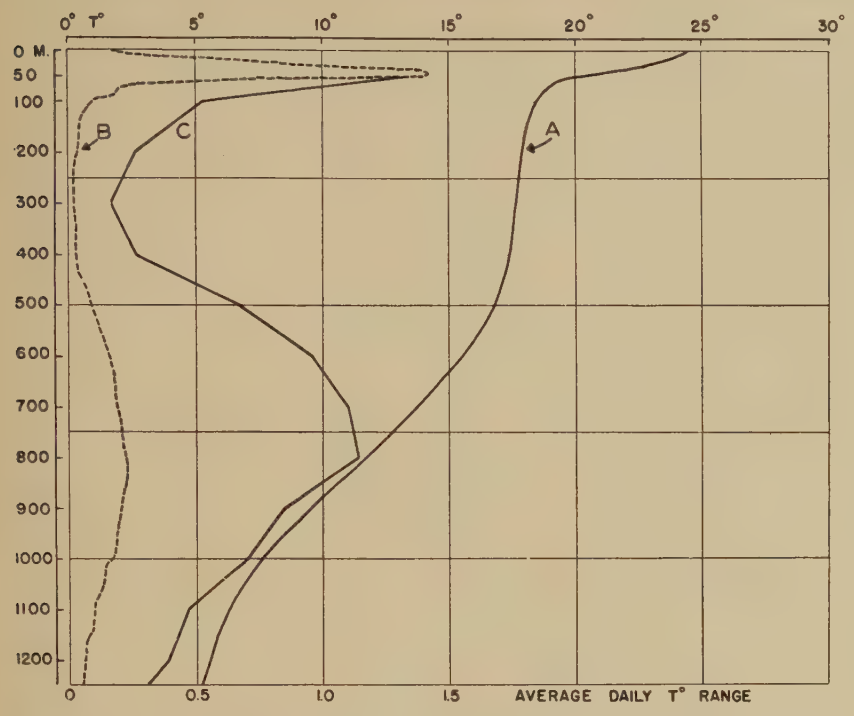

Fig. 5. A = average vertical temperature distribution (top scale); B = average vertical variation of temperature, $\Delta T°/\Delta Z \times 10^2$ (top scale); C = average daily temperature ranges at standard depths (lower scale, Table 5) for 13 days at Station 3091.

17° and 18°), between 74—129 m. in the underlying intermediately stable water, and between 39—41 m. in the overlying highly stable water; whereas, at the latter station, corresponding values were 227 m., 144—172 m. and 38—82 m. These large vertical displacements result from short-period vertical oscillations of 24 lunar hours or less, superimposed on longer period trends; characterizations of the latter, obtained by fitting straight lines to the 12 daily average depths of each isotherm at station 3091, and determining (by the method of least squares) the coefficients a and b of the general equation

$$y = a + bx,$$

are given in Table 4. The coefficient b denoting the daily change in average depth of individual isotherms, shows a pronounced relationship to vertical variation of density. In the surface layer, between 20·0° and 17·75°, the downward slope of isotherms increased from 0·59 to 9·77 m. per day; in the least stratified part of the water column, between 17·75° and 17·50°, there occurred an abrupt reversal of slope, and slightly deeper, the trend of the 17·0° isotherm sloped upward at an average rate of 6·26 m. per day. In still deeper water, with increasing stability, isothermal slopes continued upward, but at a

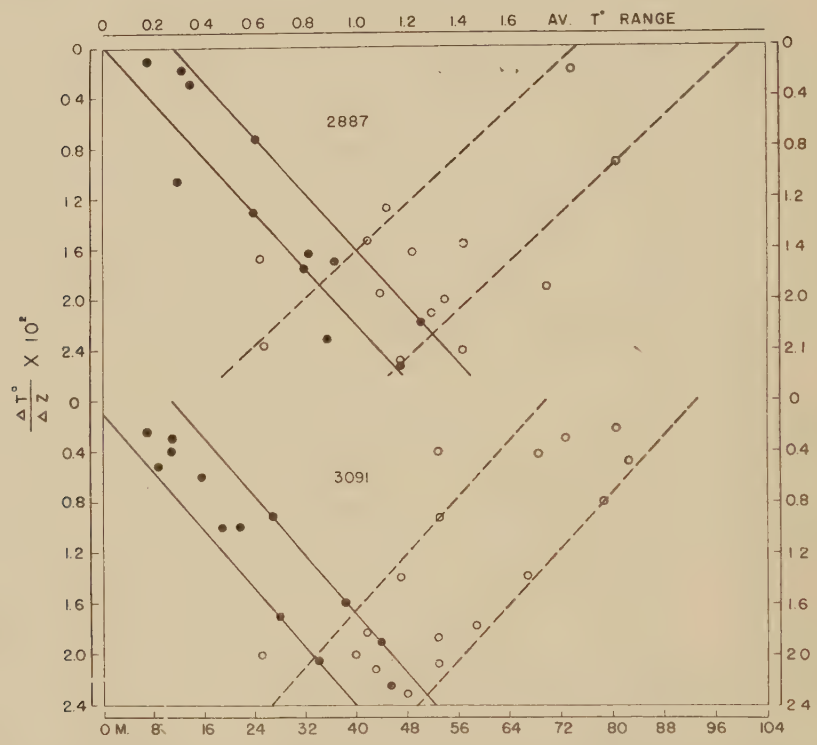

Fig. 6. Relationship of average daily temperature ranges at standard depths (closed circles) and average daily displacement ranges of isotherms (open circles) to average vertical variation of temperature, $\Delta T^\circ/\Delta Z \times 10^2$, for Stations 2887 and 3091 (Tables 2 and 5).

slower rate; at 6° the linear rate was reduced to 3·07 m. per day. Thus, because of the abrupt phase reversal between 17° and 18° isotherms the average vertical distance between them increased from 227 m. on June 17 to 367 m. on June 28; above 17·5° the water became increasingly warmer and below (to 1200 m.) increasingly colder.

Temperature Variations at Standard Depths.

Daily ranges of temperature are larger at depths where thermal stratification is greatest, a circumstance brought out for stations 2886, 2887, and 3091 by Tables 5 and 6 and Figures 4 and 5. Conditions at all three stations are essentially similar, and, as illustrated for the two latter, changes in magnitude of average daily temperature ranges are sensitive to small variations in thermal stratification. The interdependence of average daily temperature ranges and average vertical displacements of the water column, and their contrary relation to thermal stratification (Fig. 6) indicate that the damping effect of

stratification on vertical displacement is insufficient to offset increased values of the former occurring with increased stratification. Thus, at stations 2887 and 3091, between the 17° and 18° isotherms, where temperature (like density) changes slowly with depth, $\Delta T°/\Delta Z = 0{\cdot}06° \times 10^{-2}$ to $0{\cdot}9 \times 10^{-2}$, average daily temperature ranges were as low as 0·17°; in the overlying surface layer (in the vicinity of 20°—21° where $\Delta T°/\Delta Z$ attains values up to $14{\cdot}2 \times 10^{-2}$) average daily temperature ranges were up to 1·35°, while in the intermediately stratified deeper water (between 17° and 6° maximum, values of $\Delta T°/\Delta Z = 2{\cdot}3 \times 10^{-2}$ to $2{\cdot}5 \times 10^{-2}$ average daily temperature were ranges up to 1·26° (Table 5).

Comparisons of maximum and minimum daily temperature ranges (Table 6) show large day-by-day variations at identical depths, a condition inferred from the nature of daily variations in magnitudes of vertical displacements (Fig. 3). Likewise, the total temperature ranges at standard depths for the various observation periods considered are significantly large; during 12 days at station 3091 the smallest variation of 0·50° occurred in the least stratified water, and the largest of 3·52° in the deeper, more strongly stratified water (Table 6).

As a result of the previous discussion it is to be expected there will be a day-by-day change in average temperatures at standard depths, and, as illustrated for 5- and 12-day periods at station 2887 and 3091 (Table 7), the variation of average daily temperatures is smallest for depths characterized by least thermal stratification (0·04°—0·25°), and greatest (1·13°—1·28°) in the intermediately stratified water at mid-depths.

Summary.

In the waters of the western Sargasso Sea, as represented by "Atlantis" stations 2886, 2887, and 3091, continuous temperature measurements at fixed depths (to 1200—1300 m.) over time intervals up to 12 days, show average daily vertical displacements of the water particles of 24 to 97 m. and total displacements of 38 to 227 m., the larger values occurring where the water is least stable; with increasing stratification vertical motions of the water particles are damped. As a result of this phenomenon, temperature at fixed depths (for all 3 stations) showed an average daily range of 0·08° to 1·35°, and a total range for the 13-day period (station 3091) of 0·50° to 3·44°.

(Tables 2—7: see following pages)

Table 2.

Isotherm	Station 2886		Station 2887				Station 3091			
	Average depth	Average daily range	Average depth	Average daily range	Minimum daily range	Maximum daily range	Average depth	Average daily range	Minimum daily range	Maximum daily range
20·0°	—	—	98	26	21	23	56	19	5	28
19·0°	84	40	150	25	12	35	79	25	11	55
18·0°	288	54	300	74	57	94	179	69	29	107
17·75°	—	—	—	—	—	—	260	81	40	106
17·5°	393	49	449	97	36	161	367	73	34	116
17·25°	—	—	—	—	—	—	438	83	39	142
17·0°	482	36	618	81	43	117	476	79	42	149
16·0°	567	30	687	70	51	97	566	67	27	144
15·0°	625	24	733	57	39	80	631	59	26	120
14·0°	676	29	776	54	27	74	686	53	24	103
13·0°	725	38	829	57	27	85	737	53	30	108
12·0°	772	32	899	49	41	67	784	53	30	110
11·0°	814	25	954	52	47	61	829	48	30	110
10·0°	856	29	995	47	39	59	873	43	21	111
9·0°	901	31	1035	47	34	62	921	40	18	106
8·0°	953	21	1079	44	28	63	974	42	18	103
7·0°	1012	30	1135	42	33	58	1039	47	21	101
6·0°	1085	46	1211	45	34	69	1131	53	24	110
5·0°	1241	48	—	—	—	—	1293	53	27	85

Table 3.

Isotherm	Station 2887 Minimum depth	Maximum depth	Total displacement	Station 3091 Minimum depth	Maximum depth	Total displacement
20·0°	80	119	39	42	80	38
19·0°	127	168	41	49	131	82
18·0°	236	360	124	95	291	196
17·75°	—	—	—	159	386	227
17·50°	335	500	165	296	466	170
17·25°	—	—	—	375	534	159
17·0°	542	673	131	403	575	172
16·0°	631	760	129	496	668	172
15·0°	692	807	115	558	714	156
14·0°	736	853	117	608	752	144
13·0°	781	893	112	652	797	145
12·0°	839	937	98	695	850	155
11·0°	883	1000	117	738	910	172
10·0°	927	1033	106	780	950	170
9·0°	971	1069	98	831	993	162
8·0°	1021	1117	96	882	1039	157
7·0°	1091	1172	81	948	1120	172
6·0°	1176	1250	74	1032	1200	168
5·0°	—	—	—	1232	1354	122

Table 4.

Isotherm	Station 3091 $y = a + bx$ a	b	Average depth June 17	Average depth June 28
20·0°	59·26	—0·59	56·2	50·1
19·0°	88·05	—1·37	83·3	67·9
18·0°	235·30	—8·39	200·6	139·0
17·75°	324·16	—9·77	282·1	212·2
17·50°	360·97	0·85	345·2	386·0
17·25°	402·40	5·28	394·0	469·3
17·0°	433·61	6·26	427·4	506·1
16·0°	530·41	5·38	525·3	592·5
15·0°	598·58	4·82	596·5	657·9
14·0°	653·81	4·86	653·6	714·5
13·0°	705·00	4·77	706·8	765·4
12·0°	752·80	4·60	755·2	809·4
11·0°	799·71	4·28	802·5	851·3
10·0°	845·67	4·08	849·3	895·1
9·0°	894·26	3·89	898·7	941·6
8·0°	949·11	3·59	954·2	994·5
7·0°	1013·63	3·67	1016·7	1058·6
6·0°	1109·57	3·07	1110·1	1152·9
5·0°	1269·71	3·65	1288·9	1328·4

Table 5.

Depth	Station 2886		Station 2887		Station 3091	
	Average temperature	Daily average temperature range	Average temperature	Daily average temperature range	Average temperature	Daily average temperature range
0	25·22°	—	24·55°	—	24·34°	—
50	—	—	—	—	20·08°	1·35°
100	18·71°	0·64°	19·92°	0·89°	18·44°	0·54°
200	18·17°	0·08°	18·27°	0·30°	17·91°	0·27°
300	17·99°	0·18°	18·02°	0·32°	17·67°	0·17°
400	17·46°	0·13°	17·53°	0·35°	17·38°	0·27°
500	16·83°	0·31°	17·46°	0·18°	16·78°	0·67°
600	15·48°	0·47°	17·13°	0·61°	15·51°	0·96°
700	13·51°	0·63°	15·74°	1·26°	13·73°	1·10°
800	11·35°	0·65°	13·56°	0·92°	11·65°	1·14°
900	9·03°	0·65°	11·96°	0·82°	9·44°	0·85°
1000	7·19°	0·46°	9·90°	1·18°	7·56°	0·70°
1100	5·87°	0·40°	7·61°	0·80°	6·28°	0·47°
1200	5·19°	0·25°	6·13°	0·60°	5·50°	0·39°
1300	—	—	—	—	4·99°	0·22°

Table 6.

Station 2886

Depth	Minimum temperature	Maximum temperature	Total range	Minimum daily range	Maximum daily range
0	—	—	—	—	—
50	—	—	—	—	—
100	18·25°	18·99°	0·74°	0·59°	0·69°
200	18·12°	18·20°	0·08°	0·07°	0·08°
300	17·88°	18·07°	0·19°	0·17°	0·19°
400	17·39°	17·52°	0·13°	0·13°	0·13°
500	16·64°	17·03°	0·39°	0·30°	0·31°
600	15·19°	15·77°	0·58°	0·47°	0·47°
700	13·11°	13·87°	0·76°	0·62°	0·64°
800	11·04°	11·75°	0·71°	0·60°	0·69°
900	8·79°	9·48°	0·69°	0·60°	0·69°
1000	6·86°	7·51°	0·65°	0·27°	0·65°
1100	5·65°	6·06°	0·41°	0·38°	0·41°
1200	5·02°	5·30°	0·28°	0·21°	0·28°
1300	—	—	—	—	—

Station 2887

Depth	Minimum temperature	Maximum temperature	Total range	Minimum daily range	Maximum daily range
0	—	—	—	—	—
50	—	—	—	—	—
100	19·00°	21·03°	2·03°	0·57°	1·42°
200	18·17°	18·96°	0·79°	0·18°	0·32°
300	17·70°	18·20°	0·50°	0·16°	0·42°
400	17·00°	17·80°	0·80°	0·10°	0·55°
500	16·94°	17·50°	0·56°	0·04°	0·55°
600	16·47°	17·42°	0·95°	0·24°	0·93°
700	14·84°	16·77°	1·93°	0·63°	1·71°
800	12·82°	15·15°	2·33°	0·36°	1·53°
900	10·60°	12·80°	2·20°	0·45°	1·51°
1000	8·29°	11·00°	2·71°	0·94°	1·39°
1100	6·83°	8·35°	1·52°	0·64°	1·11°
1200	5·77°	6·90°	1·13°	0·27°	1·10°
1300	—	—	—	—	—

Station 3091

Depth	Minimum temperature	Maximum tempetature	Total range	Minimum daily range	Maximum daily range
0	—	—	—	—	—
50	19·00°	22·05°	3·05°	0·90°	2·20°
100	17·95°	19·38°	1·43°	0·22°	1·01°
200	17·65°	18·43°	0·78°	0·08°	0·77°
300	17·48°	17·98°	0·50°	0·06°	0·26°
400	17·04°	17·70°	0·66°	0·15°	0·51°
500	15·96°	17·37°	1·41°	0·34°	1·09°
600	14·19°	16·85°	2·66°	0·36°	1·95°
700	11·88°	15·32°	3·44°	0·47°	2·33°
800	9·61°	12·97°	3·36°	0·73°	2·50°
900	7·73°	11·25°	3·52°	0·38°	2·08°
1000	6·32°	8·85°	2·53°	0·35°	1·45°
1100	5·50°	7·20°	1·70°	0·24°	1·06°
1200	5·15°	6·00°	0·85°	0·22°	0·67°
1300	4·74°	5·27°	0·53°	0·11°	0·31°

Table 7.

Depth	Range of average daily temperature Station 2887 5 days	Station 3091 12 days
50	—	1·01°
100	0·35°	0·76°
200	0·13°	0·37°
300	0·18°	0·25°
400	0·12°	0·27°
500	0·04°	0·94°
600	0·30°	1·23°
700	1·02°	1·18°
800	1·13°	1·28°
900	0·64°	1·24°
1000	1·12°	0·98°
1100	0·54°	0·52°
1200	0·28°	0·38°
1300	—	0·29°

Fluctuations in the Racial Characters of the Plaice and the Dab.

By

Aage J. C. Jensen.

WHEN A. C. Johansen in 1929 demonstrated that the racial character of the plaice altered from year to year, he supposed that the racial character of each race was mainly determined by heredity and that probably "the increase which has been observed in the number of anal fin rays possessed by the plaice in the Belt Sea and the Western Baltic in recent years is produced by an increased supply of larvae of the North Sea race and is only of a temporary nature, and that the mean number of anal fin rays possessed by the "pure Baltic plaice" is still only about 50·0" (10).

After examination of the distribution of the racial character in the Belt Sea plaice, I was able to show that this distribution was different from the one that would result from an influx of larvae, and supposed it to be caused by an increased cross-breeding with North Sea plaice (7).

Later R. Kändler (11), in his comprehensive and elaborate disquisition, showed that an influx of larvae from the North Sea and the Kattegat cannot be of great importance either to the plaice of the Western Baltic or the Arkona Basin. Kändler further pointed out that these differences between the year-classes as well as between adjacent areas must undoubtedly be put down to the influence of various hydrographical conditions during the time at which the racial character is determined.

In his treatise Kändler further demonstrated that great alterations from year to year in the racial character occur also within the North Sea plaice. Regular Danish investigations on the racial character of ten year-classes of plaice from the eastern North Sea are now available, and on the basis of these investigations it will be reasonable to make a closer examination of the variations of racial character and to look into the causes of these fluctuations. As regards the dab a corresponding, though less comprehensive, material is to hand, which may be used as an illustration of the results achieved for the plaice.

The following points will be discussed:—
1. The variations from year to year in the number of anal fin rays of the plaice and the reliability of the fluctuations observed.
2. A comparison between the different areas.
3. The causes of the fluctuations in the number of anal fin rays of the plaice.
4. The causes of the fluctuations in the number of anal fin rays of the dab.

1. The variations from year to year in the number af anal fin rays of the plaice.

During the investigations on the plaice population of the Horns Reef area anal fin rays have been counted every year since 1932 by

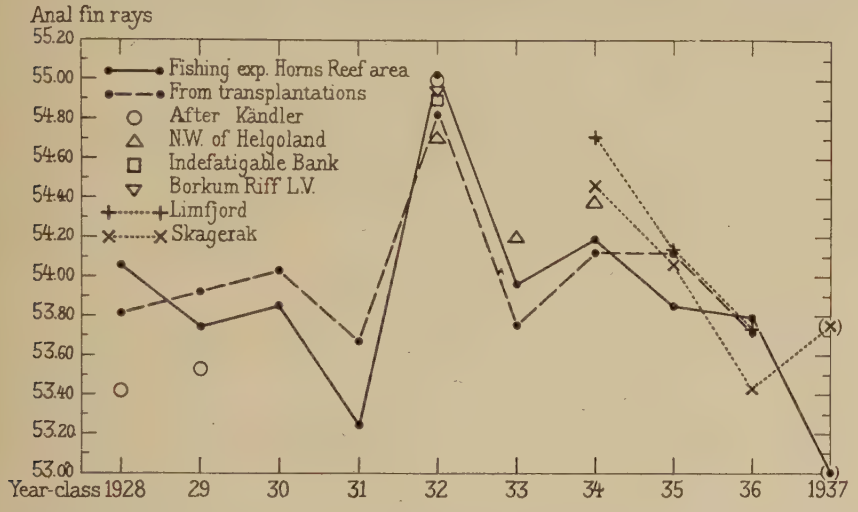

Figure 1. Comparison between the various averages of anal fin rays in plaice of year-classes 1928—37 found in the southern and eastern North Sea and western parts of the Skagerak.

Table 1.

Anal fin-rays of plaice counted during fishing experiments in the Horns Reef area.

	Year-class	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Total number of age-group investigated	I-Gr.	—	—	—	—	1	—	—	28	371	30
	II „	—	—	1	2	—	84	514	358	203	—
	III „	—	19	1	—	46	165	54	52	—	—
	IV „	51	11	—	17	19	2	2	—	—	—
	V „	19	—	11	6	—	—	—	—	—	—
	VI „	—	8	—	—	—	—	—	—	—	—
	VII „	16	4	—	—	—	—	—	—	—	—
	VIII „	2	—	—	—	—	—	—	—	—	—
Total		88	42	13	25	66	251	570	438	574	30
Mean		54·06	54·74	53·85	53·24	55·02	53·96	54·19	53·85	53·79	53·00

the present author except in 1936 and 1937 when Erik M. Poulsen and Ahlmann Andersen respectively carried out part of the counting. During the transplantations from the Horns Reef area to the Belt Sea countings of anal fin rays were made every year since 1933 by Erik M. Poulsen, who most kindly put this material at my disposal.

The extent of the results of the countings of anal fin rays during the fishing experiments are compared in Table 1. Figure 1 gives a graphical representation of the annual mean values found in the two investigations, during the fishing experiments and in connexion with the transplantations. A fairly good correspondence is found between the results of the two series of investigations, the divergences being no greater than might be expected when we consider the size of the standard deviations.

On account of the considerable spreading of the number of rays, the values found in the different investigations may of course differ rather much. Thus the following values were found for the year-classes 1934, 1935, and 1936 during the fishing experiments (numbers of plaice examined, in brackets):

Age-group	Year-class 1934	1935	1936
I	—	53·79 (28)	53·74 (371)
II	54·17 (514)	53·76 (350)	53·80 (203)
III	54·44 (54)	54·42 (52)	—

From the transplantation the following mean values were found:— Mean values of anal fin rays, the Horns Reef area (numbers of plaice examined, in brackets).

Age-group	Year-class 1928	1929	1930	1931
III	—	—	—	53·89 (19)
IV	—	54·20 (25)	53·96 (80)	53·80 (97)
V	53·75 (142)	54·19 (78)	53·99 (93)	53·55 (141)
VI	54·00 (209)	53·92 (71)	54·34 (38)	—
VII	53·28 (25)	53·12 (34)	—	—
VIII	53·11 (28)	—	—	—

Age-group	Year-class 1932	1933	1934	1935
II	—	—	53·87 (111)	54·29 (63)
III	54·51 (145)	53·74 (1181)	54·41 (587)	54·08 (620)
IV	54·92 (421)	53·88 (135)	54·08 (75)	—

The differences between the mean values found for the number of anal fin rays of the same year-class in the different years are of nearly the same size order as those observed between the individual year-classes, and there seems to be a certain regularity of the variations, so that the number shows a rising tendency until we reach the II- or III-Gr. In the following age-groups the variations seem to have no fixed tendency. In itself the rising tendency of the ray figure in the

younger age-groups is very natural, because the hindmost ray is often very small, so that it is easily overlooked if smaller fish are examined without staining[1]).

A change in the older age-groups would be due to a local change in the stock of plaice, either in such a way that plaice from another area with another number of anal fin rays influenced the average number or that the stock differentiated through an emigration from the area of plaice with the highest numbers of rays. The fluctuations found must be supposed to be due to variations of the physical conditions (see below), and consequently there must be a possibility of a differing racial character in the various parts of the nursery grounds of the plaice. It is well known that there is a constant change of place in a north-westerly direction in the areas considered (A. C. Johansen); so the plaice that have arrived in the German Bight as

Table 2.

Anal fin-rays for the different year-classes (1928—37) in the Horns Reef area (total material).

Year-class	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Anal fin-rays 47	—	—	—	1	—	3	—	—	—	—
48	2	—	—	1	—	3	2	—	1	—
49	5	3	1	5	1	21	9	7	9	—
50	16	6	5	9	6	31	34	26	19	3
51	44	16	9	28	21	91	77	69	48	2
52	67	36	14	35	39	185	130	131	79	7
53	76	43	19	57	86	266	222	206	117	8
54	97	55	46	50	121	283	300	241	128	2
55	80	41	37	43	146	201	243	206	113	7
56	56	29	39	32	99	130	158	137	69	—
57	22	11	29	16	65	71	107	61	28	1
58	23	7	20	4	38	37	43	25	13	—
59	4	3	4	3	16	5	15	9	3	—
60	—	—	2	—	3	—	3	1	—	—
61	—	—	1	—	—	—	—	2	—	—
62	—	—	—	—	—	—	—	—	—	—
63	—	—	1	—	1	—	—	—	—	—
n	492	250	227	284	642	1327	1343	1121	627	30
Mean	53·85	53·89	54·04	53·63	54·83	53·78	54·15	54·01	53·77	53·00
σ	2·09	1·95	2·21	2·08	1·95	2·41	1·98	1·89	1·92	1·74
σ_M	0·093	0·123	0·147	0·123	0·077	0·066	0·054	0·056	0·077	0·32
σ_σ	0·067	0·087	0·104	0·087	0·054	0·047	0·037	0·040	0·043	0·22
χ^2	37·7	17·1	63·7	23·7	9·1	75·2	8·2	11·1	5·1	
P	<0·01	<0·2 >0·1	<0·01	<0·2 >0·1	<0·7 >0·5	<0·01	0·7	0·6	<0·9 >0·8	

[1]) When the investigator is aware of the fact that the hindmost ray is easily overlooked, the values of the countings may become too high.

fry will gradually come to make up a constantly rising percentage of the plaice of the Horns Reef area.

By way of illustration Fig. 2 shows the distribution for the 1931 and 1932 year-classes, which showed the highest and lowest mean values, and the distributional graph is here compared to the normal distribution with the same standard deviation.

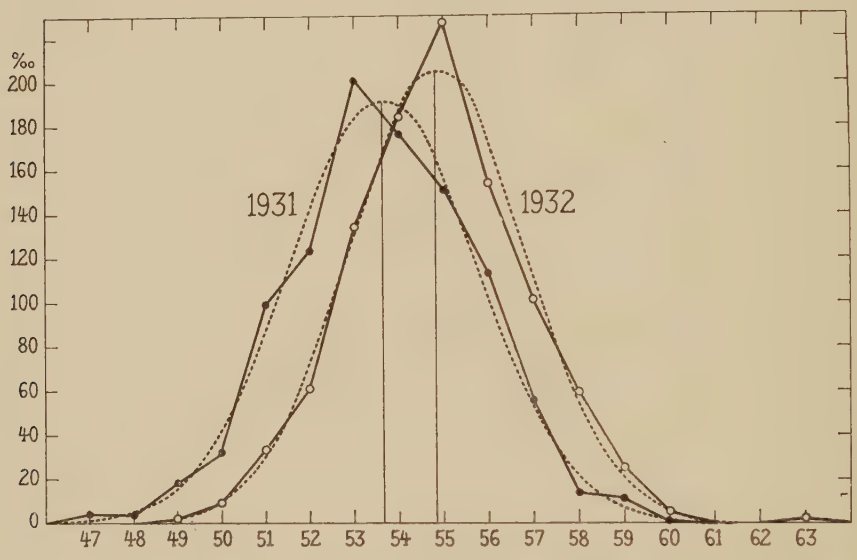

Figure 2. The frequency diagrams of anal fin rays of plaice of the year-classes 1931 and 1932, respectively, in the Horns Reef area, compared with the calculated normal frequencies (broken curves).

If we calculate the percentage distribution of anal fin rays for each of the years 1928—36 and the mean of these distributions, we get the distribution shown in Fig. 3. Here $M = 54{\cdot}001$, $\sigma = 2{\cdot}058$ and $\sigma_M = 0{\cdot}022$. Thus the mean figure for the southern North Sea seems to be very near to 54 fin rays, which was also considered in earlier investigations to be the characteristic value for the plaice of this area.

The corresponding calculated normal distribution is represented by the dotted line in Figure 3. It is noteworthy that the average distribution observed follows this graph very closely.

The values for "P" found by means of the χ^2-test for a correspondence between the normal distribution and the distribution of anal fin rays observed in the individual years show, in 3 of the 9 years between 1928 and 36, a very considerable difference between the two distributions, and only in 4 years is there a considerable degree of probability that the anal fin rays follow this law of distribution. But the average values for the per mille distribution between 1928 and 1936 show a very close conformity to this law of distribution.

The average of the values found for the standard deviation of each of the year-classes 1928—36 is 2·053, or the same value as is found if the standard deviation is calculated on the basis of the average distribution. This should seem to indicate that the size of the standard deviation is determined genotypically, but we lack experimental investigations that can answer this very important question.

2. Variation from place to place in the south-eastern North Sea.

Within the different parts of the Horns Reef area no difference of the racial character could be established. If such a difference were present, one would primarily expect it to be found between various

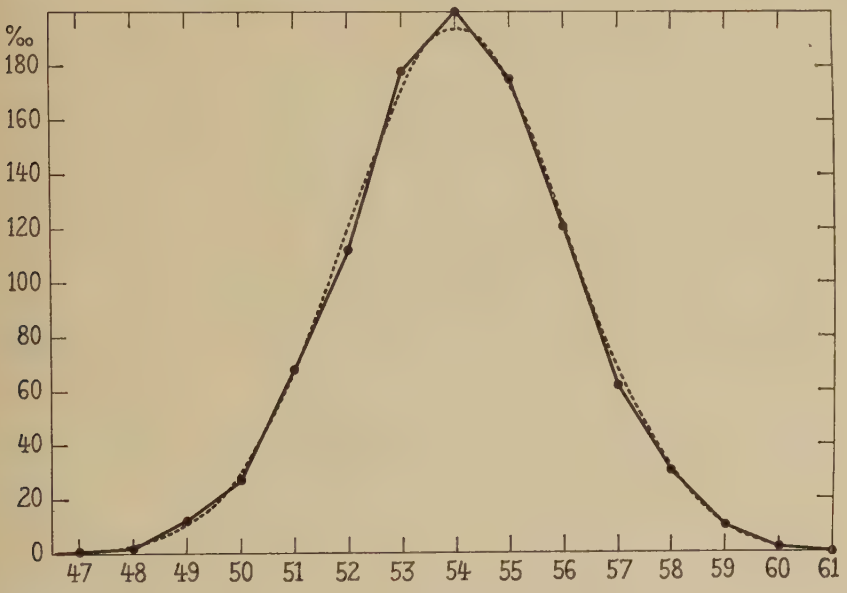

Figure 3. Average of anal fin rays of plaice in the Horns Reef area (year-classes 1928—36) compared with the calculated normal frequency (broken curve).

depths or between the areas north and south of the reef, but in these areas the II-Gr. in 1937, for instance, had the following values:—

	Mean	Number	σ	σ_M
S. of the Horns Reef, depth 6—15 m.	53·64	126		
„ „ 22—30 m.	53·66	91		
S. of the Horns Reef, total	53·65	217	1·80	0·122
N. „ „	53·93	133	1·66	0·144

Thus the difference found between the averages north and south of the Horns Reef is 0·28, with $\sigma_{Diff.} = 0 \cdot 19$.

The figures found for the II-Gr. in 1938 are:—

S. of the Horns Reef; mean 53·81 (162 ind.)
N. „ „ „ „ „ 53·83 (41 ind.)

During the examinations of the market fish at Esbjerg in 1937 and 1938 the anal fin rays were counted in the following numbers of plaice caught in the Danish seine outside the Horns Reef area (Numbers in brackets):—

	N. Lat.	E. Long.	Depth in m.	Year-class 1935	1934	1933	1932	1931
June 1937	54°45′ 54°39′	6°15′ 6°13′	38 41	—	54·38 (42)	54·20 (49)	54·71 (25)	—
„ „	53°35′	2°20′	15—38	—	—	—	54·9 (9)	—
June 1938	53°34′	5°49′	21—23	—	—	—	54·94 (17)	52·7 (10)
„ „	55°34′	6°08′	47—49	54·16 (49)	54·6 (8)	—	—	—

During his investigations on the 0- and I-Gr. in 1928—29—32—33 K ä n d l e r found the values below:—

Year-class	1928	1929	1932
German Bight	53·42 (382)	53·53 (204)	55·00 (206)
Scotland (St. Andrew's Bay)..			54·59 (225)
The Channel (Plymouth)			54·71 (99)

For the 1928 year-class K ä n d l e r carried out countings of anal fin rays partly at Heligoland, partly at Norddeich and obtained the mean values 53·38 (199 fish) and 53·53 (382 fish) respectively, and he points out that a difference in the number of anal fin rays within the same year-class can in no case be established.

In countings of anal fin rays of plaice from the Limfjord in the years 1934—38, carried out by E r i k M. P o u l s e n and A h l m a n n A n d e r s e n, the following values were found for the broods of 1934—36:—

Year-class	Anal fin rays	σ	σ_M	Number counted by:
1934	54·71	2·09	0·198	Andersen: 75 Poulsen: 36
1935	54·14	2·05	0·083	Andersen: 248 Poulsen: 370
1936	53·73	1·93	0·093	Poulsen: 425

The 1934 value is remarkable because it is 0·59 rays higher than the value found in the Horns Reef area.

$\sigma_{Diff.}$ $\sqrt{0{\cdot}054^2 + 0{\cdot}198^2} = 0{\cdot}204$, and thus the difference is nearly 3 times $\sigma_{Diff.}$.

From E r i k M. P o u l s e n's countings of anal fin rays during the

fishing experiments in the Tannis Bay in 1935—38 we have the following mean figures:—

Year-class	Anal fin rays	Number examined	σ	σ_M
1934	54·46	409	1·94	0·096
1935	54·06	274	1·65	0·100
1936	53·43	137	1·98	0·169
1937	53·75	12	—	—

The values from the different investigations are grouped in Fig. 1. In spite of the small difference between the various areas we cannot exclude the possibility that certain year-classes along the islands of West Friesland have average values that differ from the corresponding values in the Horns Reef area. Furthermore, the fact that the 1934 year-class both in the Limfjord and the Tannis Bay have higher values than the same year-class in the Horns Reef area seems to indicate that the higher values of this year-class are not due to accidental variation.

3. The causes of the fluctuations.

It is a well-known fact that Johs. Schmidt has demonstrated experimentally that differences in temperature during the first development of the larval stage cause changes in the numerical characters in *Lebistes reticulatus* and *Salmo trutta*. Experiments with other species of fish have not been carried out.

The differences in racial character observed in nature from one locality to another have been attributed to the influence of temperature, but also to the more or less land-locked character of the area in question (Schmidt), and furthermore varying salinities have been put forward as the cause of differences whether they occur from race to race or from year to year within the same race.

As regards the plaice Kändler (*loc. cit.*) has found a certain degree of covariation, (a) between the number of fin rays in the different areas and the temperature of the water, and (b) between the standard deviation and the salinity; but he is of opinion that a universal rule cannot be laid down.

It must be emphasized that within each race the variation from year to year may be expected to show a state of regular dependence on external factors. The most obvious thing is to search for these factors in the physical conditions that influence growth during the time at which the racial character in question is first observed to appear, in other words the time at which it may be supposed to be "determined".

Thus Kändler supposes that the fact that the larger (older) plaice of the 0-Gr. on the Oder Bank in 1934 had a higher ray figure than the smaller ones is due to a development of the former at higher temperature and salinity (*loc. cit.*, page 115).

If we compare the variation of the anal fin rays from year to year in the Horns Reef area to the variations in temperature, measured at the light-vessels in the southern North Sea in the winter and spring

months, we find a distinct covariation (cf. Figure 4). To obtain an idea as to which months show the closest correspondence to the number of anal fin rays we may calculate the correlation coefficients, as follows:—

Number of anal fin rays in 1928—37 correlated with the temperature at the Horns Reef L. V., bottom, in

Dec.—Jan.	r = 0·27
Jan.—Feb.	r = 0·40
Feb.—Mar.	r = 0·43
Mar.—Apr.	r = 0·30

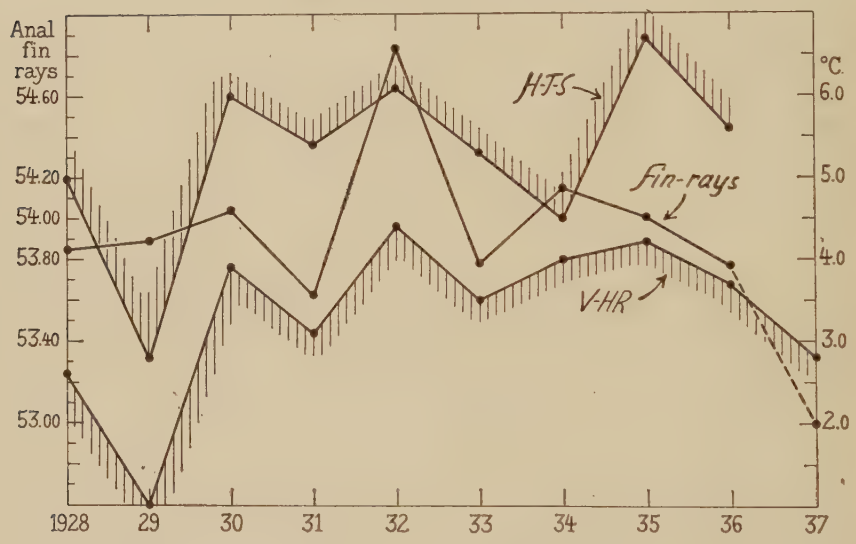

Figure 4. Average of anal fin rays of each year-class of plaice in the Horns Reef area compared with the surface temperature in January—February—March at the Haaks—Terschelling—Smith's Knoll (H—T—S), and the Vyl—Horns Reef light-vessels (V—HR) respectively.

The spawning time of the North Sea plaice is generally reckoned to be the months between December and March with a maximum in (or about) the latter half of January (1). It should be strongly emphasized that the series of years covered by our material is too short to allow a determination of the time at which the temperature exercises the greatest influence on the number of anal fin rays, but the result of the calculation seems to indicate that the influence is most perceptible at a comparatively early stage of the development of the larvae, during the first or second week after hatching.

It further appears from a comparison between the number of anal fin rays and the temperature in the Southern Bight that the temperatures of this area show a poorer correspondence with the variations

of the ray figure in the Horns Reef area than the temperatures at the Vyl and Horns Reef light-vessels. Accordingly, the spawning areas near the Horns Reef seem to be the principal places of origin of the fry of the Horns Reef area.

It is to be seen in Figure 4 that the correspondence between numbers of anal fin rays and temperature is not complete; especially in the years 1929 and 1934 the ray figures diverge from what would be expected from the temperature. It is a most important question whether other causes must therefore be supposed to have a share in determining the variation of the racial character.

If the temperature influences the number of anal fin rays, this number must vary from year to year according to the temperature of the area in which the larvae lived at the time when the racial character was determined; the situation of this area changes from year to year, but in Fig. 4 the comparison is based on temperatures of fixed localities.

Undoubtedly, the plaice in the Horns Reef area receive a varying amount of fry from the different spawning localities in the different years. In most years there is sure to be a more or less considerable influx from the principal spawning locality of the plaice in the southern North Sea, the Southern Bight, but in some years wind and current may nearly totally prevent the influx of larvae from this area.

According to Carruthers, 1925, page 112 (3), persistent winds from the south and south-east in the Southern Bight produce currents that run nearly in the opposite direction to the usual one, so that the water movement is directed towards the north and north-west instead of towards the north-east.

The frequency of S. and SE. winds at the Horns Reef in January—February was as follows:

	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Jan.	14	39	20	22	6	42	3	18	22	55
Feb.	19	63	56	30	21	41	4	13	49	24

It is noticed that the frequency of southerly and south-easterly winds was particularly great in 1929.

However, the low temperatures of 1929 shown in Fig. 4 occurred only in a zone along the coasts of the continent where the light-vessels are found, but not south and south-west of the Dogger Bank where the temperatures in 1929 were as follows (calculated by the aid of C. I. D. (4)):—

	Lat. 53°51'N.—Long. 1°E.	Carré Lat. 54°N.—Long. 4°E.
Jan.	5·9	5·7
Feb.	4·2	3·1
Mar.	4·1	3·1

It should be remembered that Bückmann found a good covariation between the frequency of SW. and W. winds in February and the frequency of the year-classes in the German Bight with the

exception of the very year 1929. By way of explanation he suggests that the cold may have delayed spawning (2).

The other year in which the number of anal fin rays deviated from the expected figure was 1934, when the temperature was about average in the Horns Reef area and considerably below average in the south-western North Sea while the number of anal fin rays (54·15) was rather much above the normal. From the table showing the frequency of southerly and south-westerly winds it is seen that this year was remarkable for its uncommonly low frequency of winds from these directions in January and February. The corresponding marked predominance of northerly and north-westerly winds must be expected to have caused the population of the Horns Reef area to be recruited to a higher degree than is normally the case, from regions situated farther northwards in the North Sea where the temperature was higher. Thus the surface temperature in 1934 was 6·6° in January, 5·9° in February and 5·4° in March (C. I. D. (4)) in Field 55° N., 5° E. (E. and SE. of Tail End). As will appear from Figure 1 the number of anal fin rays was much higher at Thyborøn and in the Skagerak than in the Horns Reef area in 1934. It should be noted that in this year the approximation of the distribution of the fin rays to the normal law was rather slight, possibly on account of an *admixture* of plaice fry with a higher number of anal fin rays.

Also westerly winds were extremely frequent in this year. Altogether there is *a fairly distinct positive correlation between the frequency of westerly winds and the number of anal fin rays.* But no connexion can be traced between the variations of salinity, neither in

Numbers of anal fin rays in various age-groups of plaice in the North Sea and the Skagerak.

Year-class	Area	Number	Anal fin rays	Year investigated
1894	Near Thyborøn	25	54·80	1895
1895	„ „	55	54·33	„
1901 (a.o.)	Horns Reef area	224	54·27	1903
1902	Near Esbjerg	114	54·37	„
1903	Tannis Bay	125	54·32	1905
1904	SW. of Hirshals	436	53·96	„
„	E. of Hirshals	449	54·11	„
1905	Near Thyborøn	173	54·30	„
„	E. of Hirshals	153	54·34	1906
1906	„ „ „	206	54·19	„
1913	6 miles W. of Hornum	12	53·5	1920
1914	„ „ „ „ „	56	53·98	„
1915	„ „ „ „ „	70	54·23	„
1916	„ „ „ „ „	51	54·10	„
„	40 miles SSW. of Graadyb	22	54·32	1922
1917	„ „ „ „ „	49	53·80	„
1918	„ „ „ „ „	103	54·24	„
1919	„ „ „ „ „	20	54·45	„

the Southern Bight nor at the Horns Reef, and the variations of the anal fin rays.

As regards the connexion with the temperature a change of 1° C. corresponds to a change in the number of anal fin rays of about 0·4 ray.

From previous years we have some racial investigations carried out by A. C. Johansen.

In most of these years, too, the variations of the ray figure may be compared to the variations of temperature. For 1918 and 1919 we have no temperature observations because the lightvessels had been

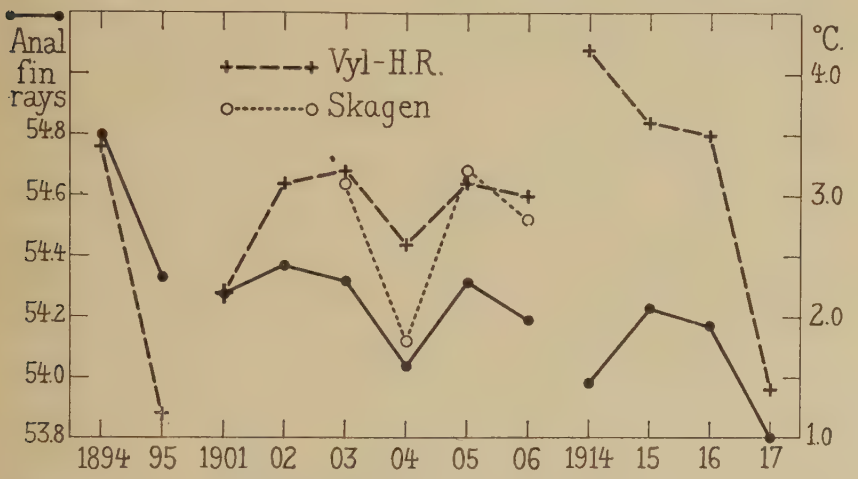

Figure 5. Average of anal fin rays of each year-class of plaice in the Horns Reef area and in the Skagerak compared with the surface temperature in January—February—March at the Vyl—Horns Reef and at the Skaw light-vessels.

removed. The connexion appears from Fig. 5. A considerable degree of correspondence is observed. An exception is formed by the year 1914, in which the number of anal fin rays for some reason or other was about 54·0 in spite of the very high temperature. Other years showing high numbers of anal fin rays in comparison to the temperature were 1894 and 1895, but again it is not possible to explain these deviations from the wind conditions.

The variation from the North Sea to other marine areas.

The number of anal fin rays in the North Sea as a whole is higher than in the waters inside the Skaw; it decreases through the Kattegat and the Belt Sea, and the lowest value occurs in the western Baltic. Correspondingly the western Baltic shows the lowest winter temperature within these waters (6).

A contributory cause of the lowest value being found in the western

Baltic is possibly that a few hybrids between plaice and flounder have been classed as plaice because the appearance of some of these hybrids differs little from that of the plaice.

Strodtmann and Kändler (12) have shown that the frequency of hybrids between plaice and flounder is much higher in the western Baltic (at Eckernförde, Travemünde and Warnemünde) than in the Baltic proper (the Arkona, Bornholm, and Gothland Basins), and further that the frequency of hybrids varies in different years, being highest in years when the quantities of plaice fry are small. The explanation offered is that the spawning of the plaice in these years is often delayed by a period of intense cold, so that it overlaps that of the flounder. "In solchen ungünstigen Brutjahren zählten wir auf manchen Jungfischplätzen oft ebensoviele Bastarde, ja, bisweilen noch mehr als Schollen", while only about 5 per cent. appeared in other years. Strodtmann and Kändler (*loc. cit.*, page 191) further emphasize the fact that the hybrids in some cases can hardly be distinguished from the plaice, more particularly within the 0-Gr. when the thorny character of the scales along the lateral line and at the bases of the anal and dorsal fins has not yet developed.

On a superficial view the plaice at Iceland might seem to form an exception from the rule of a positive correlation between temperature and number of anal fin rays, because Tåning has shown that the highest values for numbers of vertebrae are found on the east, north and north-west coasts, i.e., in the coldest waters (13). According to Duncker there is a positive, though weak, correlation between the numbers of anal fin rays and vertebrae, and so one might also expect to find the highest number of anal fin rays in the coldest areas at Iceland; but this question cannot be answered on the basis of the present material. As demonstrated by Tåning, the plaice on the eastern and northern coasts of Iceland in part originate from the fry carried hither from the principal spawning place on the southern and western coasts by the coastal current. But as the temperature in the spring months, particularly in the western part of the country, is lowest near the coast, and the current that carries along the fry is most rapid at some distance from the coast, the fry carried to the eastern and northern coasts must be expected to show a higher number of anal fin rays than the fry that remained in the water off the southern and western coasts.

4. Causes of the annual variations in the ray figure of the dab.

Like the plaice, the dab shows a considerable variation in the number of anal fin rays from one year-class to another (8). As regards the plaice there seems to be a distinct dependence on temperature conditions, although this dependence is concealed in several years by the effects of the current carrying in eggs and fry from various hatching areas. There is therefore reason to consider whether a similar state of affairs may be established in the case of the dab.

As is known, the North Sea dab principally spawns in the southern North Sea at depths between 20 and 40 m.; the spawning takes place mainly in March—May, mostly a little earlier in the southernmost than in the northernmost part of the area (Heincke, Ehrenbaum; e.g., Ehrenbaum, 1936, page 215 (5)). Off Thyborøn the number of anal fin rays is found to be higher than in the Horns Reef area, but so far we are unable to decide whether this is due to a somewhat later spawning.

In the table below the average numbers of anal fin rays in the Horns Reef area for the year-classes 1927—30 and 1933—35 are compared with the temperatures at the Horns Reef, bottom (30 m.), and with the difference of barometric pressure between Fanø and the Skaw and between Fanø and Copenhagen in the second quarter of the same years.

Year-class	Anal fin rays	C.°	Barom. Diff. Fanø—the Skaw	1/10 mm. Fanø—Copenhagen
1927	57·4	8·2	32	8
1928	57·1	6·3	24	4
1929	56·0	5·2	23	—1
1930	55·8	7·3	6	—9
1933	56·5	7·1	13	—3
1934	56·3	8·2	12	—11
1935	57·1	8·2	13	—6

It is noted that the covariation with the temperature is rather small, but there is a possibility that the effect of the temperature is masked by the influence on the recruiting of the area with tiny fry which is exercised by the current in transporting the larvae. There is particularly good correspondence with the pressure gradient Fanø—Copenhagen, that is to say, with the northerly winds, which might be expected because, as already mentioned, the number of anal fin rays is higher off Thyborøn than in the Horns Reef area.

According to A. C. Johansen (9) the spawning season of the dab in the Kattegat and the Belt Sea is principally the months of April, May, June, and July. If we now use the waters of the Northern Belt Sea, the Great Belt and Smaalandshavet for a comparison of the numbers of anal fin rays in the individual year-classes with the temperature of the lower water layers, we find the following fairly close correspondence:—

Year-class	Anal fin rays	Temperature Schultz Grund, Bottom, in June—July—August.
1929	54·1	7·6° C.
1930	54·4	8·6
1931	53·9	7·1
1932	54·1	8·3
1933	54·3	7·9
1934	54·3	8·8
1935	54·8	9·4

It is seen that 1° C. corresponds to about 0·4 anal fin rays. Moreover it is found to apply for the dab, as was formerly established in the case of the plaice (7), that no distinct connexion exists between the bottom salinity (the strength of the inflow) and the number of anal fin rays.

Summary.

As regards both the plaice and the dab the number of anal fin rays seems to be positively correlated with the temperature of the water during the time at which the larvae are quite small. 1° C. corresponds to about 0·4 anal fin rays. The currents are of great importance to the racial character of the individual localities because the influx from the various hatching areas varies from year to year.

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Über das Vorkommen von Heringslaich im Magen von Schellfischen aus dem Gebiet der norwegischen Nordwest-Küste.

Von

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AUF zwei während März und April 1938 von der Biologischen Anstalt Helgoland unternommenen wissenschaftlichen Fischdampferreisen nach der norwegischen Küste, der Bären Insel und dem Barentsmeer wurden auf verschiedenen Fangplätzen[1]) kleine Proben von Schellfischmägen als Vorbereitung für spätere, ausführliche Nahrungs-Untersuchungen entnommen. Bei der Untersuchung des Materials stellte sich heraus, dass vor der norwegischen Nordwest-Küste ein überraschend grosser Teil der Fische Heringslaich gefressen hatte. Ausserdem war von Interesse, dass die Mägen bei den Laichfressern in weit stärkerem Masse gefüllt waren als bei denjenigen Tieren, die andere Nahrung zu sich genommen hatten.

Im Weiteren soll nun über die Folgerungen, die sich aus unseren Beobachtungen für die Laichverhältnisse ergeben (A u r i c h) und über die Bedeutung des Heringslaichs als Nahrung der Schellfische (S t i e r) berichtet werden.

Vorkommen von Heringseiern und Lage der Laichplätze.

Die Funde von Heringslaich in den Schellfischmägen verteilen sich auf drei verschiedene Gebiete: Svends Grund, Röst Bank und Halten Bank. Weiter südlich, auf der Romsdal Bank (Storeggen, über 300 m. Tiefe), im Südwesten der Halten Bank (über 380—430 m. Tiefe) und ferner auf den Barentsmeer Stationen nördlich Finnmarken sowie im Gebiet der Bären Insel wurden dagegen keine Laichfresser unter den Schellfischen angetroffen.

*) Die Untersuchungen wurden mit Mitteln des Deutschen Reichsministeriums für Ernährung und Landwirtschaft durchgeführt.

[1]) Die Lage der Stationen, an denen Magenuntersuchungen durchgeführt wurden, ist in unserer Karte durch kleine Kreise bezeichnet:— für die Stationen der Fahrt vom 17. März—1. April 1938 durch einfache Kreise, für die der Fahrt vom 10.—26. April 1938 durch Doppelkreise. Siehe ferner Übersicht I.

Übersicht I.

Übersicht über die Gebiete, in denen Fischmägen konserviert wurden.

Gebiet			Tiefe	Datum (1938)	Zahl der untersuchten Mägen	Zahl der Mägen mit Eiern
Romsdal Bank	62°50′N.	4°42′W.	270 m.	11.IV.	2	—
Westl. Halten Bank	64°32′N.	6°00′O.	380—430 m.	10.IV.	2	—
Halten Bank	64°55′N.	8°43′O.	175—185 m.	11.IV.	3	3
Röst Bank	68°15′N.	11°23′O.	140—150 m.	31.III.	20	12
„	68°20′N.	10°25′O.	480—500 m.	14.IV.	2	—
„ (Kante)	68°21′N.	11° 4′O.	350 m.	14.IV.	6	3
Svends Grund	69°43′N.	16°32′O.	200—300 m.	28.III.	58	3
Slettnes (Finnm.) ..	71°40′N.	28° 8′O.	370 m.	16.IV.	6	—
„ ..	72° 9′N.	28° 7′O.	270 m.	16.IV.	4	—
„ ..	72°53′N.	28° 3′O.	340 m.	16.IV.	5	—
Südwestl. Bären Insel	74° 8′N.	17°52′O.	200 m.	19.IV.	5	—
„	74°23′N.	17°10′O.	200 m.	19.IV.	4	—

Übersicht II.

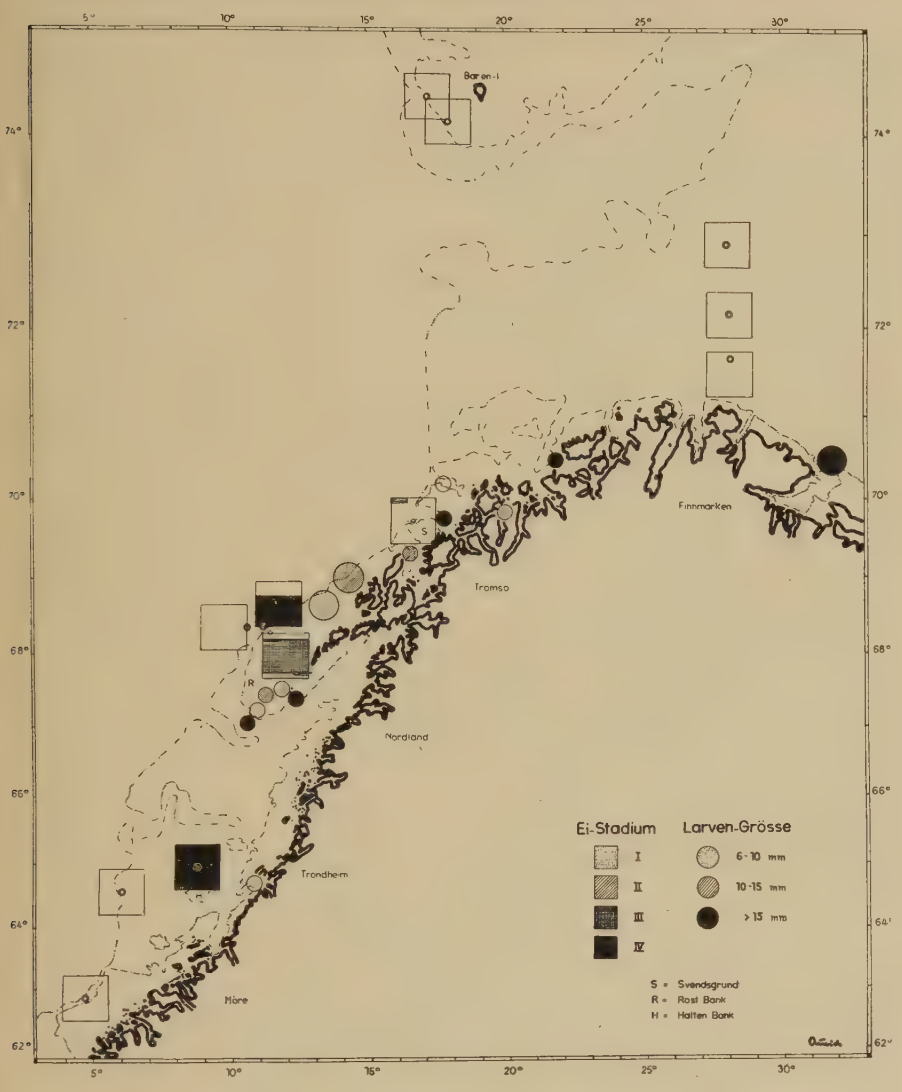
Gebiet[1]) und Fangdatum (1938)		Halten Bank 11.IV	Röst Bank 31.III-1.IV	Röst Bank (Kante) 14.IV	Svends Grund 28.-30.III.
t° in ... m. Tiefe		6·91° 180 m.	— —	6·90° 175 m.	-
%-Häufigkeit der Eier enthaltenden Mägen		100[2])	85	67	3
Zahl der untersuchten Mägen		3	20	6	58
%-Anteil der Eier am Gesamtinhalt der Mägen.....		93—100	89—99	64—89	90—100
Durchschnitts-Wert.....		98	95	75	95
Zahl der Eier je Magen (in 1000)		6—16	8—57	5—27	4—84
Durchschnitts-Wert.....		11	20	13	44
Grössen-Gruppe der Schellfische, in cm.....		14—50	50—70	50—70	50—70
Verdauungs-Grad[3]) Durchschnittl. ... % der Eier	schwach verdaut	13	54	22	16
	stärker —	87	46	78	84
%-Häufigkeit der verschiedenen Entwicklungsstadien der Eier	I	0	11	0	65
	II	0	1	0	35
	III	2	87	4	0
	IV	98	1	96	0

1) Angaben für Position und Tiefe s. Übers. I.

2) Von dieser Station wurden nur Mägen von Schellfischen, die Laich gefressen hatten, untersucht, sodass der Wert von 100 % sicher etwas zu hoch ist.

3) Bei den "schwach verdauten" Eiern zeigten Dotterkugel und Embryo noch scharfe Umrisse; der Dotter war bei den Entwicklungsstadien I—II trüb weisslichgelb, bei den Stadien II—IV relativ klar und gelb gefärbt.

Bei den "stärker verdauten" Eiern waren die betreffenden Umrisslinien mehr aufgelöst, der Dotter teilweise oder ganz zerfallen und von trüber, grünlichgrauer Farbe.



Einen Überblick über unsere Beobachtungen gibt die beigefügte Karte. Zur Darstellung der prozentualen Häufigkeit der Laichfresser, der "spawny haddocks", auf den verschiedenen Fangplätzen wurden an allen Stationen, wo Magenuntersuchungen vorgenommen wurden, Quadrate gleicher Grösse gezeichnet, deren schwarz oder durch Schraffen ausgefüllte Fläche dem Anteil der Laichfresser an der Gesamtzahl der untersuchten Schellfische entspricht.

Um eine Vorstellung über den Zeitpunkt der Laichablage in den verschiedenen Fanggebieten zu erhalten, wurden bei den Heringseiern

4 in ihrer Entwicklung verschieden weit fortgeschrittene Stadien unterschieden:—

	Ei-Stadium	Darstellung in der Karte
I	Keimscheiben-Stadium	punktiert
II	Embryo kürzer als der halbe Dotter-Umfang	einfach schraffiert
III	Embryo länger als der halbe Dotter-Umfang	kreuzweise schraffiert
IV	ebenso, Augen dunkel pigmentiert	schwarz

Beachtet man die *Tiefenverhältnisse* auf den Fangplätzen, so zeigt sich, dass an den flacheren Stationen ein wesentlich grösserer Teil der Schellfischmägen Heringseier enthielt als auf den tieferen Stellen. So hatten auf Röst Bank bei 140—150 m. Tiefe 85 % der untersuchten Fische Laich gefressen, bei 350 m. Tiefe nur noch 65 % und bei 480—500 m. waren garkeine Laichfresser mehr vorhanden. Auf Halten Bank, bei einer Tiefe von 175—185 m., waren nach einer Bemerkung im Fahrt-Tagebuch (Dr. Lundbeck) die Mägen "fast alle vollgestopft mit Laich" (der in unserer Karte und der Übersicht II angeführte Wert von 100 % bezieht sich auf die wenigen, näher untersuchten Mägen und ist im ganzen wahrscheinlich etwas zu hoch). Auf der tiefer gelegenen Station am Nordrand von Svends Grund, bei 200—300 m. Tiefe, betrug dagegen der Anteil der Laichfresser nur 5 %.

Diese Feststellung ist nicht überraschend, da der Hering zum Laichen bekanntlich die flacheren Teile der Bänke bevorzugt. Nach Runnström (1934) beträgt die grösste Tiefe, bis zu der Heringseier mittels des Bodengreifers nachgewiesen werden konnten, an der norwegischen Südwest-Küste (bei Haugesund) 150 m. Wir dürfen also annehmen, dass die Fische, deren Mägen Eier enthielten, diese auf den flacheren Stationen an Ort und Stelle gefressen hatten, während die in grösserer Tiefe angetroffenen Laichfresser sicher erst von den Heringslaichplätzen her zugewandert waren. Darauf deuten auch unsere Untersuchungen über den *Verdauungszustand* der Eier hin (vergleiche die folgende Übersicht II). Auf den drei tieferen Stationen über 175—350 m. Tiefe war durchschnittlich ein beträchtlich grösserer Teil der Eier, 78—87 %, stärker verdaut als auf dem Flach der Röst Bank über 140—150 m. Tiefe, wo etwa die Hälfte der Eier, 54 %, einen noch sehr guten Erhaltungszustand zeigte. Dagegen liessen sich aus dem *Anteil der Eier am Gesamtinhalt der Mägen* keinerlei Anhaltspunkte hierfür entnehmen. Vielmehr ergab sich, dass der Laich in den meisten Fällen über 90 % des Gesamtgewichts der einzelnen Mageninhalte ausmachte, die Tiere also fast ausschliesslich Heringslaich gefressen hatten. Nur auf der tieferen Röst-Station (auf 350 m. Tiefe) hatten einige Fische neben den Eiern auch noch andere Nahrung (Crustaceen, Mollusken und Echinodermen) in etwas grösserer Menge, bis zu 36 % des Gesamt-Mageninhalts, gefressen.

Entwicklungsstufe der Eier und Laichzeit.

Die letzte Spalte der Übersicht (vergleiche auch die Karte) gibt einen Einblick in die Alterszusammensetzung der Eier auf den einzelnen Stationen. Es zeigte sich, dass mit Ausnahme von Svends Grund, wo allerdings nur 2 der untersuchten Mägen Heringslaich enthielten, die Eier grösstenteils auf dem gleichen Altersstadium standen und zwar nicht nur innerhalb eines einzelnen Magens, sondern in sämtlichen, von der gleichen Station stammenden Mägen. Wir dürfen daraus schliessen, dass die an einer Stelle gefangenen Laichfresser jeweils den gleichen Heringslaichplatz heimgesucht hatten und dass dort im wesentlichen nur eine einmalige Laichablage stattgefunden hatte. Wahrscheinlich stammen auch die schlüpfreifen Eier (Stadium IV), die am 14. IV. im Tiefen querab Röst gefunden wurden, von demselben Laichakt wie die jüngeren, noch auf Stadium III stehenden, die wir 14 Tage zuvor, am 31. III. im flachen Wasser antrafen. Denn bei den niedrigen Bodentemperaturen von 5·8—6·9°C., die während der Fahrten auf den Bänken gemessen wurden, beträgt die Entwicklungsdauer der Heringseier bis zum Schlüpfen sicher mehr als 20 Tage[2]); und wenn ein Analogieschluss von den Befunden A p s t e i n s (1909) über die Entwicklung pelagischer Fischeier (Scholle, Flunder, Kabeljau) erlaubt ist, beansprucht die Entwicklung von Beginn des Stadium III bis zum Schlüpfen reichlich die Hälfte der gesamten Entwicklungsdauer, d.h. in unserem Falle über 10 Tage. Auf jeden Fall scheinen in unserem Gebiet nur wenige, zeitlich getrennte Laichablagen stattgefunden zu haben, denn sonst müssten wir Eier der verschiedensten Entwicklungsstufen gleichzeitig nebeneinander in den Mägen vorfinden.

Die Bedeutung unserer Beobachtungen für die Kenntnis über die Biologie des norwegischen Herings.

Die Feststellung, dass der Hering auch vor der Nordwest-Küste Norwegens laicht, wurde erstmalig von R u n n s t r ö m (1934) auf Grund der Verbreitung der Heringslarven in diesem Küstenabschnitt gemacht. Die Larvenfunde R u n n s t r ö m s sind auf unserer Karte durch Kreise dargestellt, die entsprechend den unterschiedenen Grössengruppen verschieden ausgefüllt sind und deren Grösse gleichzeitig einen Hinweis auf die Häufigkeit der Beobachtungen (nicht gleich der Häufigkeit der Larven, über die R u n n s t r ö m keine genaueren Angaben macht) geben soll:— kleine Kreise bedeuten 1—4, grosse 5—10 Einzelbeobachtungen während der Jahre 1900—1932.

Wie man aus der Karte erkennen kann, stimmen die Ergebnisse unserer Untersuchungen gut mit den Beobachtungen R u n n s t r ö m s

[2]) Nach K o t t h a u s (1939) beträgt die Entwicklungsdauer der Heringseier bei einer Durchschnitts-Temperatur von

12·3°C.	7—9 Tage
10·7	10—12 „
8·7	14—18 „
8·3	17—20 „

überein. Die Verbreitung der frisch geschlüpften, 6—10 mm. langen Larven fällt annähernd in das Gebiet unserer Eifunde, wogegen die älteren Larven, besonders die über 15 mm. langen, eine deutliche Verdriftung in Richtung der längs der Küste setzenden Strömung nach Nordosten bis Osten (Finnmarken) zeigen.

Diese Ausbreitungsrichtung gibt einen wichtigen Anhaltspunkt für die Klärung der Frage nach der Herkunft der Herings-Laichschwärme. Auf Grund der morphologischen Identität zwischen norwegischem und Barentsmeer-Hering glaubte Rabinerson (1925), dass der letztere zum Laichen nach den damals allein bekannten Laichplätzen an der Südwest-Küste Norwegens ziehe und auch aus diesem Gebiet seinen jährlichen Nachwuchs ergänze. Dieser Ansicht wurde jedoch später von Makuschok (1932) widersprochen, welcher nachwies, dass die Strömungsgeschwindigkeit längs der norwegischen Küste nur etwa zur Hälfte ausreichen würde, um die Larven innerhalb eines Jahres von Südwest-Norwegen bis zur Murman-Küste zu verfrachten, wo die jüngsten Heringe wenig älter als 1 Jahr waren. Ferner sprach gegen Rabinerson's Annahme, dass im Barentsmeer erwachsene Heringe beobachtet wurden, die nur etwa 1 Monat vor ihrer völligen Laichreife standen und in dieser Zeit unmöglich hätten den weiten Weg nach den südlichen Laichplätzen zurücklegen können. Makuschok vertrat daher die Ansicht, dass der Barentsmeer-Hering in seinem Wohngebiet selbst laiche, obwohl dort bisher weder Eier noch junge Larven nachgewiesen werden konnten.

Durch die Entdeckung der nördlichen Laichplätze wird nun auch diese Annahme überflüssig; denn berücksichtigt man ausser dem Küstenstrom auch die atlantische Strömung, so erscheint die Strömungsgeschwindigkeit völlig ausreichend, um die Larven im Laufe eines Jahres von den Laichplätzen im Lofoten-Gebiet bis zur Murman-Küste zu verfrachten (Runnström, loc. cit.).

An Bedeutung bleibt das Laichen vor der Nordwest-Küste weit hinter dem auf den bekannten südlichen Laichgründen zurück, wie sich sowohl aus der kurzen Laichdauer im Norden — nach unseren Feststellungen hatte auf den einzelnen Bänken wahrscheinlich nur je eine einmalige Laichablage stattgefunden — als auch aus dem spärlichen Auftreten frischgeschlüpfter Larven ergibt. Nach Runnström wurden von 1900—1932 nur in 6 Jahren junge, 6—10 mm. lange Larven beobachtet, meist in sehr geringer Zahl, 1—12 je Jahr; nur 1928 waren es insgesamt 610 Stück. Allerdings ist die Seltenheit der Funde zum Teil auch durch die recht ungenügende Durchforschung des nördlichen Gebietes bedingt. Infolge dieses Mangels an genaueren Untersuchungen lässt sich vorläufig noch nicht entscheiden, ob das Laichen des Herings auf den nördlichen Gründen regelmässig erfolgt oder nur sporadisch wie z.B. auf den ebenfalls durch den Fang von "spawny haddocks" und jüngster Larven bekannt gewordenen Laichplätzen im Gebiet der Kleinen Fischer und Jütland Bank (Duge 1903, Johansen 1927).

Nach den neuesten Berichten über die im Zusammenhang mit der

Erwärmung der arktischen und subarktischen Gebiete während der letzten Jahre erfolgten biologischen Veränderungen (Jensen 1939) wird ausserdem auch in unserem Fall mit einer Ausdehnung des ursprünglichen Laichgebietes nach Norden zu rechnen sein, wie es für den Islandhering bereits nachgewiesen werden konnte (Jensen, loc. cit., Seite 39).

Die Bedeutung der Heringseier als Schellfischnahrung.

Der in den Mägen vorgefundene Heringslaich ist auch im Hinblick auf die Ernährung der Fische nicht ohne Bedeutung. Die Menge der gefressenen Heringseier beträgt je Magen im Durchschnitt 41·7 g. Die neben den Eiern noch gefressene Nahrung beträgt je Magen 4·1 g. und entspricht fast genau der Nahrungsmenge der Fische, die keine Heringseier gefressen hatten und deren Mageninhalt ein Durchschnittsgewicht von 4·2 g. ergab. (Etwas anders ist die Gewichtsverteilung von Ei- und anderer Nahrung nur bei Röst, wo, wie oben bereits erwähnt wurde, die Menge anderweitiger Nahrung je Magen grössere Durchschnittswerte ergab. Bei dem Gesamtdurchschnitt tritt diese Abweichung aber nicht mehr in Erscheinung). Hieraus geht hervor, dass der Heringslaich als eine für die Tiere willkommene Gelegenheitsnahrung gedeutet werden kann. Zur Erklärung der grösstenteils so auffallend geringen Mengen an Mageninhalt kann zweierlei angeführt werden. Es wäre möglich, dass die Tiere, die geschlechtsreif waren, wenig gefressen hatten, während die unreifen viel gefressen hatten. Dies kann an dem vorliegenden Material nicht im einzelnen nachgeprüft werden, da die Tiere, deren Mägen konserviert wurden, nicht individuell auf Reife untersucht worden sind. Es ist aber unwahrscheinlich, denn die für andere Fischereiuntersuchungen ausgeführten Reifebestimmungen ergaben, dass alle Tiere auf den in Frage kommenden Stationen geschlechtsreif waren. Ausserdem hatten auch die bei der Bären Insel untersuchten unreifen Fische wenig gefressen. Es ist deshalb wahrscheinlicher, dass die befischten Gebiete, von denen konservierte Schellfischmägen mitgenommen wurden, nahrungsarm sind. Nur diejenigen Schellfische, die sich auf den Heringslaichplätzen befanden, scheinen Gelegenheit zu reichlicher Nahrungsaufnahme gehabt und auch ausgenutzt zu haben.

Da weitere Veröffentlichungen über die Fischmagenuntersuchungen vorläufig nicht geplant sind, sollen noch einige allgemeine Ergebnisse der Untersuchungen kurz zusammengefasst werden. Betrachten wir die Beteiligung der einzelnen Tiergruppen an der Zusammensetzung der Schellfischnahrung, so ergeben sich keinerlei Gesetzmässigkeiten, die auf eine Bevorzugung einer bestimmten Art oder deren auffällige Häufigkeit in einem Gebiet hindeuten würden. Es ergibt sich nur ganz allgemein ein Überwiegen der Molluskennahrung an der norwegischen Küste, während nördlich Finnmarken und westlich der Bären Insel Crustaceen in weitaus grösster Menge in den Mägen vorhanden waren.

— Die Unterschiede beziehen sich auf die Anzahl der Nährtiere, nicht auf das Gewicht derselben. — Es liess sich nicht feststellen, ob bei der Nahrungsaufnahme ein feststehender tageszeitlicher Rhythmus eingehalten wird (Franz 1910, Wilke 1939).

Summary.

The present investigation deals with a small collection of haddock stomachs from the NW. coast of Norway, N. of Finmark and W. of Bear Island. Part of the material from the Norwegian NW. coast contained rich quantities of herring eggs in the stomachs.

Stomachs containing herring eggs were more numerous at shallow-water stations than deep-water stations, presumably because herring spawning mostly takes place on shallow banks. The majority of eggs recorded at each fishing place were of the same age and but few spawnings — separated in time — seem to have taken place.

Makuschok's theory, that a migration of herring larvae with the current (Rabinerson) from the S. coast of Norway to the Barents Sea within one year is not possible, and that the spawning grounds of the Barents Sea herring are to be found in these waters, seems disproved by the discovery (Runnström) in the Lofoten area of spawning places, which is definitely supported by our observations. The comparatively few data yielded by the present material obviously cannot throw light on the question of regular return to the spawning grounds.

The investigations characterize the waters NW. of Norway as well as those N. of Finmark and W. of Bear Island as poor in respect of fish-food. All stomachs — barring those filled with herring eggs — showed scarcity of food. The small quantities of food can hardly be due to any decrease in appetite on account of spawning, as simultaneously some stomachs were filled with herring eggs while others were empty, specially N. of Finmark and W. of Bear Island where the stock of haddock, according to our present knowledge on maturity, consists exclusively of immature fish.

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Prediction of the Time of Setting of Oyster Spat and a Method of Control.

By

B. Havinga.

OYSTER CULTURE in Holland began in 1870. From that time on the production of cultivated oysters increased continuously for many years, until in about 1890 a number of 30 million oysters was reached. This can be considered as the normal production of the Easter-Scheldt in later years, although there have been many and wide fluctuations which are inherent in a culture that is practised on the bottom of the sea, and in a climate moreover of which the extremes on the low side are in summer disastrous for propagation and in winter for the life of the oyster. This caused a narrow correlation between the climatic pecularities of a season and the number of oysters that settled on the collectors or that were produced.

In the years since 1931, however, the line of production shows, independently of climatic conditions, a pronounced decline, which is caused by two different factors that began their activity simultaneously, namely, the slipper limpet (*Crepidula fornicata*) and shell disease. The coincidence of both these factors proved so fatal that by about 1935 the oyster banks were nearly depopulated. In 1930 the production was 38 million oysters — many of which were exported for relaying — and in 1936 only 8 million.

Before the invasion of the slipper limpet, in 1929, the eastern part of the Easter-Scheldt had always been a very important centre for obtaining oyster spat. In the first 30 years of oyster culture, the largest part of the spat settled on limed tiles, since laying of shells was not practised then.

About 1900 the planting of shells began in an ever increasing degree. The shells required much less labour, and were much cheaper, and in 1925 the enormous quantity of 47,000 m^3. of shells, all of *Cardium edule*, were sown over the banks of the eastern part of the Easter-Scheldt. As soon, however, as the slipper limpet appeared, it found in these shells a selected cultch, and within a few years the banks were covered with thick layers of this pest and the young oysters were suppressed. During the first 2 years it may be estimated that the number of slipper limpets increased about 200-fold every year. The

production of young oysters was therefore reduced to a minimum and the oysters left, were for a large part affected by shell disease (Havinga, 1931). A direct suppression of the slipper limpet and the disease was impossible, and so we had to look for indirect methods to relieve the situation, and first of all it was necessary to stimulate the production of more oysters as much as possible.

The slipper limpet only caused damage in the eastern part of the Easter-Scheldt, as it did not propagate much in the centre and the western part. On the tiles — that had still remained in use, though in small numbers — laid in the western parts, only a few slipper limpets settled, and these could be killed during the regular cleaning and inspection of the tiles, or when this was not done, they were left on the tiles as the spat was removed and planted out on the beds. Afterwards it proved also that the young oysters from these tiles were less affected by the shell disease.

Cultivation on tiles showed therefore a way to get out of the trouble, and the Government has given as much help as possible to the renewed development of this method.

As the banks were heavily depleted, the production of larvae had much decreased, and it was decided therefore to import oysters from Brittany in order to get a sufficient amount of larvae.

A very important factor in the tile method — and in general in the planting of other kinds of cultch — is that the tiles should be put into the water a short time before the spat will settle, or else they become less effective through a covering of mud and silt or living organisms. I have therefore tried to work out a method to assist the oyster cultivator in this respect.

Spawning and development of the larvae, both within and without the shell, is very dependent on the temperature of the water, and in our summer this is a factor of which nothing can be said beforehand. A prediction of the time of spatfall can therefore only be of value when the period is not too long, especially since a very large proportion of the free swimming larval oysters does not settle at all during unfavourable weather.

Orton (1937, and also in earlier publications) suggests opening a number of oysters, and determining the percentage of blacksick individuals; "spat may then be anticipated to settle 10 to 14 days from the discovery of the blacksick stages. The density of the subsequent fall will be proportional to the percentage of blacksick oysters if healthy growth and settlement occurs" (p. 121). In our country this "healthy growth" will only occur under especially favourable circumstances, and a high percentage of blacksick oysters will often be followed by a poor spatfall. The dominant factor is largely the weather; a low temperature, often accompanied by strong winds causing heavy floods and ebbs that sweep away great quantities of larval oysters, will never be followed by a good spatfall, even though a large percentage of blacksick oysters occurred 10 or 14 days before. This

period is much too long, for at the beginning it is impossible to foresee what the weather will be in the meantime, and how, according to that, the larvae will develop. Orton has also felt this difficulty himself, for a few pages on he remarks, "There is no doubt that larvae occur in abundance every year. It is likely that removal of larvae from the grounds in tidal currents is a frequent cause of partial failure, but other unknown factors almost certainly operate. Cold summers with low water temperatures may still be regarded as inimical, notwithstanding good settlements of spat in the still waters of tanks and ponds at low temperatures".

The French method seems to me much better. It consists of counting the larvae in the plankton. Many data on this method are to be found in the "Revue des Travaux de l'Office des Pêches Maritimes"; among the numerous papers on this subject I may mention those of Borde (1935), Boury (1928 and 1930) and Lambert (1935). The French investigators did not restrict themselves to counting the larvae, but they also distinguished two stages, the young larvae of the first stage with a straight hinge-line, and those of the second stage, nearly ready for settling, with a convex hinge-line. The proportion between the number of second stage larvae and the total number of larvae is called by a somewhat misleading term "coefficient de fixation". The presence of many larvae and a high "coefficient de fixation" (e.g., 0·30) are indications that a good spatfall may be expected. As this coefficient is also a function of the total number of larvae, it can be much influenced by the number of very young larvae, which, however, have no influence at all on the spatfall that may be expected in the first few days following.

The oyster larvae are caught with ordinary plankton nets towed through the water, generally on the surface, for 5 or 10 minutes. From the whole catch a small proportion is taken with an ordinary pipette, and the larvae are counted in a known part of this (Boury, 1928).

The French investigators have not established a control for their method, at least, not systematically. It is not known if on a certain day (or short period) on which a great spatfall is expected or predicted, it really occurred. The frequency of sampling is not very high, sometimes not more than 2 samples a week.

When I was faced with the problem of assisting the oyster cultivator by finding the right time to put his tiles into the water, I was well aware that this problem would be difficult. In our uncertain climate it is impossible to predict for more than a fairly short time ahead. In order to proceed as safely as possible, I tried to eliminate every source of error in the catching and counting of the larvae, so that this could not be the reason for a failure, and I worked out a method for controlling the prediction.

Towing a plankton net through the water is rather a rough method for quantitative purposes — one does not know if the larvae are evenly distributed vertically, and the net may be clogged up to a

varying extent by plankton or detritus — and I therefore decided to pump up a certain quantity of water and filter it through a plankton net specially devised for this work[1]); 100 l., or when many larvae were present, 50 l. of water were sufficient. The suction hose of the pump was fairly long, so that the open end could be moved through the upper and deeper layers of the water; this, however, was only done at first; later the samples were taken 60 cm. above the bottom. The samples were taken daily, precisely at the time of low water, at two different places on the banks. The sampling was done on board the police-boats which are always present on the banks. The larvae of the whole catch were counted and measured and the presence of the pigment spot noted. An investigation in this manner takes much time; from the end of June to about the end of July one student needs all his time to examine the two daily samples, but it seems impossible to simplify the work. The great local variability in the number of larvae makes it necessary to investigate at least two samples each day, and the great differences between one day and another — especially on the stations on which many of the mother oysters are concentrated, and the young larvae are set free — make it dangerous to make the period between two samples longer than one day.

If the investigation of the samples gives information of possible value to the cultivator, a bulletin announcing the prospects on the spatfall is distributed. If many large larvae are present, there is not much difficulty, and a good spatfall in the first few days is predicted. If the larvae are scanty, this information is also published, for it may prevent the cultivator from putting his cultch into the water without a reasonable chance of a good spatfall. If large quantities of young larvae occur, this is generally also announced, although with much reservation on account of the weather. Over a longer period this information, even if not quite certain, may be advantageous to the cultivator, for it takes many days to put large numbers of tiles into the water, and he has time then to prepare everything and await the subsequent bulletins.

When so much work is required, the question arises what the results are, and if they are reliable. These questions cannot be answered by the practical oyster culture as regards every separate prediction. Thus it is not known in which period the spat has settled on the tiles, and it is also impossible to count the very young spat on the tiles, as they are not easily discerned. We determined therefore to undertake special experiments to decide whether the best spatfall is indeed obtained in that period in which we had expected it. This part of the work was done by Dr. A. G r y n s at Bergen op Zoom, to whom I am much indebted not only for this special part of the investigation, but also for help and suggestion in general.

[1]) We have also tried nets made of copper wire; these can be constructed without any projecting seam and edge. I found, however, that the copper wire becomes thickened and the net looses much of its filtering power.

Concrete boxes, open at the upper side and with long narrow holes on two opposite side walls, were made in which three 13 × 18 cm. glass plates could by placed at an angle of 45°. The plates were coated with a mixture of cement (1 part), lime (2 parts), sand (2 parts), and water (2 parts)[2]). The boxes — in the first year 2, but later 5 — containing the plates were exposed for 3 days, a somewhat arbitrarily chosen period. A shorter period would be too inconvenient, while the changing of the plates in the 5 boxes at different places gives much trouble. By comparing the results of all these 3-day periods it is possible to decide when the spatfall has been good and when not. The maximal 3-day-old spat on the plates is, however, too little to be discerned quite clearly, and to be counted. Therefore after exposure the plates are put into a floating wooden box, two opposite sides of which are covered with fine-meshed silk cloth (size of the meshes in diagonal about 0·1 mm.) where they are left for 6 days. In this box the spat grow up to such a size that they can be counted without any difficulty. The silk cloth allows water to flow through with food particles, and prevents oyster larvae coming in, and settling on the glass. After this growing-up period the young oysters are so large that they can be distinguished with a lens from young *Balanus, Crepidula,* and *Mytilus.*

During the 4 years the experiments were going on, the control glasses gave many data on the reliability of the method. It is not my intention to discuss these results in detail. As a rule they are satisfactory, or even better. The best results are obtained during a summer with a long series of warm days in July. Then there is a very good correlation between the number of the spat on the glass plates and the number of larvae in the plankton a few days before. This occurred in 1935, the first year of these investigations; the largest number of spat on the glass plates was found exactly in the 3-day period in which it was predicted. Also the other fluctuations in the spatfall during that year in the 3-day periods had been anticipated very well by the number and the state of development of the larvae in the plankton.

Another illustrative example was found in 1938. It was cold then throughout July. Sometimes great numbers of young larvae occurred, but they did not grow up well. Just as predicted, there was only a poor spatfall at that time. In the beginning of August came a spell of warm weather and a good spatfall could be predicted for the middle of that month, and was indeed also found on the control glasses.

If, however, the weather is unstable, many difficulties are met with. For example, if a spell of warm weather that has stimulated the spawning of large numbers of free-living larvae is suddenly broken,

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[2]) The coating must be quite dry, and the lime saturated with carbonic acid, before the plates are put into the water, otherwise the spat does not set well on the somewhat slimy lime, while a layer of sand grains sticks to it. If there is not enough time for the lime to harden, the plates can be treated with a solution of bicarbonate of soda. It is preferable to use glass ground on both sides, as the lime holds much better on this than on smooth glass.

nearly all the larvae will be destroyed. The spatfall on the control glasses will be very poor, and the prediction, made while the weather was yet warm, will not be fulfilled. There are, therefore, two very important factors that must co-operate for a very rich settlement of spat, namely, a large number of larvae and a high temperature.

As one does not know the course of the temperature beforehand, a prediction for a long period ahead is always affected by this factor of uncertainty, which diminishes in proportion as the period is shorter. This implies that if one wishes to go safely, the greatest attention must be paid to the number of old (large) larvae and the period of the prediction must not be very long. Therefore measuring the larvae is indispensable[3]). Replacing this measuring by counting the number of larvae with pigment spots or with a curved hinge-line may be much easier; this has, however, not the same value. For larvae of this kind are the oldest of all, and are quite near settling — perhaps they have already settled before the forecast bulletin has reached the oyster cultivator — and the number of these tells nothing about the number of the somewhat younger ones that will settle within a few days.

The combination of the counting and measuring of the larvae with the control system has convinced us that the method, as it is in use now, can be of much help to the oyster cultivator in finding the right dates for laying out his cultch, but also that in our climatic conditions the method cannot be much simplified without loosing much of its value. The oyster cultivators appreciate the work to an increasing degree; while there was at first only an inactive interest in the bulletins, the cultivators now often ask what the prospects are. During the 4 years the investigations have been going on, the cultivators have already found that it was to their advantage to follow the indications of the bulletins.

In the above I have given a concise description of our method of predicting the most likely time of the settling of oyster spat, as it was worked out in 1935 and has been carried out now for 4 years. When I began, our knowledge of the life history of the oyster larvae was rather scanty, but these many experiments and investigations, not only on counting and measuring the larvae, but also on the biology of the larvae in general, have greatly elucidated the matter. These investigations are now done by Mr. P. K o r r i n g a, who is preparing an elaborate paper on the biology of the oyster larvae in which a description of the details of the counting, etc. of the larvae will also be given.

[3]) The size of the larvae can in practice be considered as a good estimate of their age and stage of development. It must, however, be remarked that in the beginning of the season the young larvae are somewhat larger than towards the end of it.

Résumé.

Une diminution sérieuse de la production d'huîtres en Hollande nous a conduit à recourir à l'assistance des cultivateurs d'huîtres. Une des mesures consiste à développer une méthode pour prédire l'époque dans laquelle les conditions sont favorables à la fixation du naissain. Elle est fondée sur une numération et un mesurage des larves d'huîtres dans des prélèvements quantitatifs d'eau.

En plus les prédictions sont continuellement contrôlées par l'emplacement de plaques de verre chaulées dans l'eau pendant trois jours.

En général les résultats des plaques de contrôle ont confirmé les prédictions; pourtant il faut tenir compte du fait, que l'exactitude diminue rapidement avec la longueur de l'époque anticipée, dû à l'instabilité du temps. La pratique a montré qu'il est avantageux de suivre les indications. —

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Note on a Secular Variation of the Current at the Lightvessels "Horns-Rev" and "Vyl".

By

Helge Thomsen.

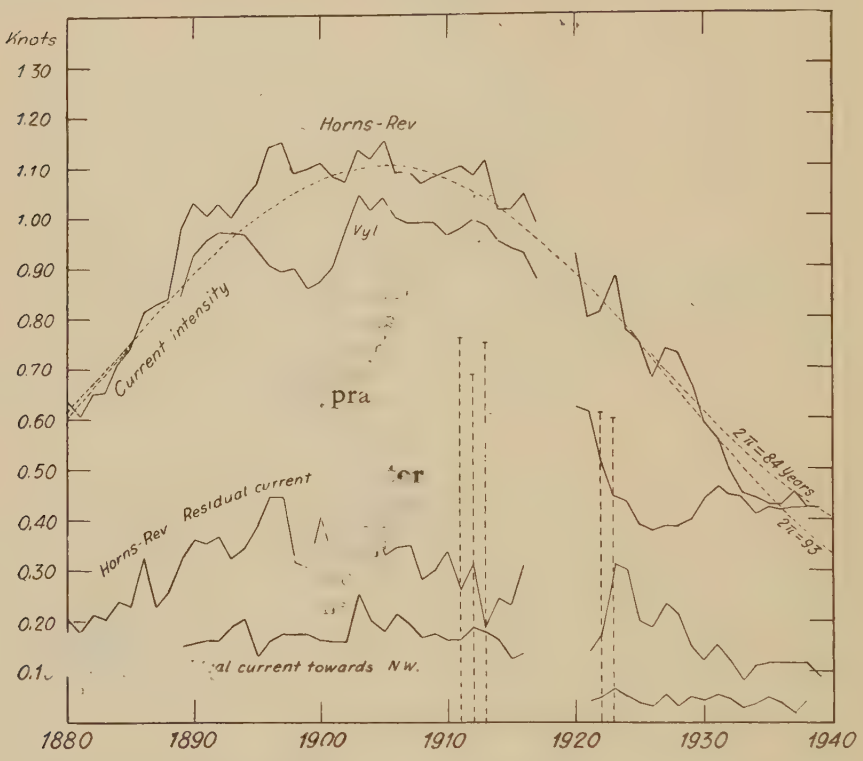
DURING more than half a century the Danish Meteorological Institute has collected 4-hourly observations of the surface current from the Danish lightvessels. In the North Sea such observations were initiated in 1878 at the L. V. "Horns-Rev" (55°34′0 N., 7°19′8 E.) and in 1888 at the L. V. "Vyl" (55°21′8 N., 7°41′0 E). With the exception of the period April, 1917, to October, 1920, when both lightvessels were withdrawn, these observations have been continued without essential interruptions until September, 1939, when both lightvessels again were withdrawn.

The speed of the current is estimated in knots with one decimal, and the direction is recorded by one of the 16 compass points. During the years 1880—1896 only decade means, monthly and yearly means were published, but from 1897 the actual observations have been published in *Nautical-Meteorological Annual.*

In the accompanying figure the two upper fulldrawn curves illustrate the variation of the yearly mean intensity of the current at "Horns-Rev" and "Vyl" during 60, resp. 51 years. By the yearly mean intensity of the current is understood the sum of all observed speeds of the current during the year disregarding the direction, divided by the number of the observations.

It is seen that both curves on the whole are ascending until about 1904. After that time they descend, at first slowly, but after 1913—14 more quickly. The decrease of the curves is quick at "Vyl", where a minimum is reached in 1926, slower at "Horns-Rev", where the decrease does not cease until 1933. At both lightvessels the annual mean intensity of the current has for the last few years been slightly above 0·4 knots, which only amounts to about ⅓ of the intensity of the current in 1904.

This fact is very surprising. It must be admitted that the currents only have been estimated, but the agreement between the two curves shows that the phenomenon cannot be explained by the supposition of



a change in the observers' estimation of the current velocity, a supposition, which also for other reasons is improbable. Both at "Horns-Rev" and at "Vyl" the tidal currents are dominant, and the currents are generally running towards the one of two opposite directions. The table below shows the frequency percentage of currents towards different directions:—

Horns-Rev		Vyl
NW.: 1·8 %		
NNW.: 53·8 „	58·3 %	NW.: 54·4 %
N.: 2·7 „		
SE.: 2·8 „		
SSE.: 32·6 „	37·2 %	SE.: 44·0 %
S.: 1·8 „		
Other directions: 4·5 „		
No current: 0·0 „		No current: 1·6 %

The yearly mean residual current at "Vyl" has been calculated by subtracting the sum of all current velocities towards SE. during the year from the sum of all velocities towards NW. and dividing the

difference by the total number of observations. The same procedure has been followed for "Horns-Rev", but in this case currents towards NW. and N. have been regarded as currents towards NNW., and currents towards SE. and S. as currents towards SSE., disregarding currents towards other directions.

In the figure is illustrated the variation of thus computed annual mean residual currents. It is seen that the residual current at first has been increasing, but since 190? on the whole decreasing, and during recent years it has only amounted to about ¼ of the residual current in 1903.

As the residual current only slightly contributes to the yearly mean current intensity, the demonstrated variation of the current intensity must have been caused substantially by variation of the intensity of the tidal current. If it is presumed that the residual current was constant (direction as well as speed) during the year, the mean current intensity as here calculated would with great approximation be equal to the mean tidal current intensity. The speed and the direction of the residual current are however, varying and therefore the mean current intensity, as here calculated, can only approximately be regarded as the mean intensity of the tidal current.

Harmonic analysis has been carried out on current measurements made by means of Jacobsen's current meter at "Horns-Rev". According to Doodson[1]) the following values have been found for the half major axis of the M_2-ellipse at a depth of 4 m.: 1911: 38·9 cm./sec., 1912: 33·8 cm./sec., 1913: 38·7 cm./sec., 1922: 31·4 cm./sec. and 1923: 30·7 cm./sec. These values, converted into knots, have been entered in the figure (vertical broken lines). Calculating means of the 3 former values and of the two latter respectively, it is seen that the half major axis in 1922/23 amounts to 85 % of the 1911/12/13 value. The mean intensity of the surface current according to the curve for the years 1922/23 amounts to 77 % of its 1911/12/13 value, which is in satisfactory concordance with the above mentioned 85 %.

A glance at the curve illustrating the variation of the current intensity at "Horns-Rev" makes one think of a sinus-oid. Unfortunately the series of observations are not sufficiently long to allow a direct statement of a possible period from the variation of the current intensities as calculated here; it is however obvious, that the length of a probable major period must be more than 70 years.

One should *a priori* think that a variation of the tidal current of a long period should exhibit the same period as the tide-generating force. According to Hans Pettersson[2]) the tide-generating force shows a period of 84 to 93 years. In the figure is entered a sinus-oid with a period of 84 years and a half amplitude of 0·37 knots. It is seen

[1]) A. T. Doodson: Current observations at Horn's Rev, Varne and Smith's Knoll in the years 1922 and 1923. Journ. du Conseil., Vol. V, No. 1, 1930.

[2]) Hans Pettersson: Long periodical variations of the tide-generating force. Publ. de Circ., No. 65, 1913.

that the sinus-oid fits fairly well but so does another sinus-oid with a period of 93 years and a half amplitude of 0·45 knots.

The supposition that the demonstrated variation of the tidal current should be due to the long-periodical variation of the tide-generating force calculated by Pettersson involves however several problems, because the maximum value of the tide-generating force in the course of 84 to 93 years only varies by 2 $^0/_{00}$ of the absolute maximum value, whereas in the course of 4½ years it should vary by 13 $^0/_{00}$. Pettersson states, however, that these values must be regarded as lower limits.

Although the variation of the tide-generating force is not by far of the same order as the variation of the intensity of the tidal current, one cannot beforehand reject the supposition of a causality. The currents at other places might have increased to compensate for the loss of energy of the tidal currents at "Horns-Rev" and "Vyl". In this connexion it is perhaps of significance that the lightvessels are situated near an amphidromy.

It is obvious, that a solution of the problems connected to the variation of the currents at "Horns-Rev" and "Vyl" is of great theoretical and practical importance, and it is hoped that a closer examination of the current observations and of the tide gauge records now commenced will throw light upon some of the problems.

Copenhagen, December 15th, 1939.

Reviews.

1) **P. M. van Riel.** "Programme of research and preparations." Snellius-Exped. Vol. I, Voyage, Chap. 1, pp. 1—37, 3 figs, 9 plates. Leiden, 1937.

2) **P. M. van Riel.** "The voyage in the Netherlands East-Indies. With a list of stations, a large route chart and 16 detail charts." Snellius-Exped. Vol. I, Voyage, Chap. 3, pp. 85—164, 17 figs, 17 charts. Leiden, 1938.

3) **S. W. Visser.** "Surface-Observations, Temperature, Salinity, Densities." Snellius-Exped. Vol. II, Oceanogr. Res. Pt. 4, pp. 1—60, 20 figs, 4 charts. Leiden, 1938.

Die Veröffentlichungen über die wissenschaftlichen Ergebnisse der "Snellius"-Expedition, eine der Grosstaten auf ozeanographischem Gebiet des letzten Jahrzehnts, schreiten rüstig vorwärts. Nachdem in dieser Zeitschrift (Vol. VII, Nr. 2, S. 212 ff.) der Leiter der Expedition, P. M. van Riel, 1932 einen allgemeinen Überblick über das Geleistete gegeben hat, konnte Referent ebenda (Vol. X, Nr. 3, S. 327) 1935 die Lotungen und die meisterhaften Tiefenkarten der niederländisch-indischen Meere samt der für den Wasseraustausch so wichtigen Frage der Schwellentiefen an der Hand von Vol. II, part 2 des Reisewerkes besprechen.

Die zwei ersten Arbeiten der drei oben aufgeführten Titel aus dem Vol. I bringen nun zunächst die notwendigen Unterlagen für den gesamten Reiseverlauf und für die einzelnen Stationsuntersuchungen. Eine nützliche, mit den Umrisslinien Europas unterdruckte Karte lehrt, dass das Arbeitsgebiet im Malaiischen Archipel bei etwa 3 Millionen km^2. Fläche in Europa von Gibraltar bis zum Bosporus und von Südnorwegen bis Sizilien reichen würde. Dem Texte voran steht ein Bild von Capt. J. L. H. Luymes, Hydrograph der Niederländischen Marine, der um das Zustandekommen der Forschungsfahrt ganz hervorragend sich verdient gemacht. Der Text lehrt uns die sorgfältigen wissenschaftlich-technischen Vorbereitungen kennen, darunter eine wichtige kurze Erprobungsreise nach dem Englischen Kanal. In gewissem Sinne betrachtet P. M. van Riel auch die gesamte Reise nach Hinter-Indien noch als Vorbereitung. Dabei sind aber schon, z. B. im Roten Meere und im Indischen offenen Ozean, beachtenswerte Tiefseebeobachtungen erzielt worden, die z. B. Helge Thomsen im *Journal du Conseil* (Vol. VIII, Nr. 1) gelegentlich einer Untersuchung über die Zirkulation in der indischen Tiefsee schon 1933 mit verwertet hat; eine Notiz van Riels weist darauf hin, dass besonders in den Angaben der Bodentiefen jetzt einige Abänderungen

von den durch ihn vorläufig in den *Annalen der Hydrographie* 1932, S. 402 ff. gegebenen Werten vorgenommen werden müssen.

Die Reisen im Archipel selbst erfolgten in drei grossen Abschnitten, wobei Soerabaia stets der Hauptstützpunkt war. So günstig überall die Wetterverhältnisse in diesen äquatornahen Gegenden sich gestalten, verglichen mit Wind und See in anderen Breiten, so wurde doch auf die Monsune, auf Regenzeit u. a. bei der Ausführung der Einzelreisen natürlich Rücksicht genommen. Auch machten in den z. T. recht engen Meeresstrassen die Strömungen schwer zu schaffen; so hatte man in der Makasser-Strasse beispielsweise mit einer Süd-Strömung von mehr als 3 Knoten zu tun. Den chemischen Arbeiten wurde durch die Teilnahme von zwei Chemikern weitgehend Rechnung getragen. Ankerstationen sind mehrfach durchgeführt, desgleichen wurden die üblichen Serienbeobachtungen durch Wiederholungen auf zeitliche Variation ergänzt, besonders innerhalb der troposphärischen Tiefen. Wiederum, wie schon 1935, sei auf die sehr wertvolle und klare Karte hingewiesen, die neben der wesentlichen Bodengestalt der Becken und Tröge deren Tiefwasseraustausch mit den zwei angrenzenden Weltmeeren durch *einen* Blick überschauen lässt. Ein Dutzend Tafeln mit photographischen Aufnahmen von Land und Leuten in jenen wunderbar schönen Gegenden und vom Leben an Bord umrahmen diesen Bericht.

Dr. Vissers Bearbeitung des ozeanographischen Oberflächenmaterials, soweit t°, S $^0/_{00}$ und σ_t in Betracht kommen, beginnt mit einer ausführlichen und kritischen Erörterung der nur scheinbar einfachen Messung der "wahren" Oberflächentemperatur. Man ist auf "Snellius" bemüht gewesen, mittels eines in 1·2 m. Tiefe registrierenden Thermographen[1]), mittels der sonst üblichen Schlagpützenmethode von Bord aus und sogar mittels Kippthermometer die Wärmeverhältnisse der Oberfläche und der unmittelbar darunter liegenden, den Atmosphärilien entrückten Schicht zu erkunden. Ist das Schiff in Fahrt, so kommt durch seine Fahrtwelle ein weiterer, die Unsicherheit vermehrender Faktor hinzu; auch turbulente Strömungen in Meeresstrassen verfälschen leicht das durchschnittliche Temperaturbild. Die Aufgabe gipfelt schliesslich in der speziellen Frage: soll die meteorologisch-klimatologisch bedeutsame Temperatur der Grenzfläche von Wasser und Luft gemessen werden oder soll die ozeanographisch wichtigere Temperatur einer von den periodischen und unperiodischen Änderungen freien obersten Wasserschicht ermittelt werden? *Ein* Resultat bestätigt auch die "Snellius"-Expedition, dass die meist auf Handelsschiffen angewandte Methode der Entnahme einer Probe durch eine Pütze infolge Abkühlung/Verdunstung erheblich zu niedrige Temperaturen liefert, je höher das Schiff, desto mehr. Den Unterschied zwischen Oberflächentemperatur und Lufttemperatur gibt Visser im Gesamtdurchschnitt auf 0°8 zu Gunsten des Wassers; ob dieser Wert für die unmittelbare Berührungsfläche beider Medien gelten darf, erscheint dem Referenten zweifelhaft. Die sorgsame Analyse des jährlichen Ganges der Oberflächentemperatur zwischen 10 N. und 10 S. Breite, im speziellen die graphische Darstellung durch zwei Figuren lehrt, dass, in guter Übereinstimmung mit anderen Quellen, 2 Maxima und 2 Minima schon allein aus den "Snellius"-Werten sich ergeben; sie fallen für 1 N. bis 1 S. Breite auf April und November (Maxima) und auf Februar und August (Minima).

Besonders wertvoll sind vier, je 3 Monate zusammenfassende Karten der

[1]) Vergl. H. C. Hamaker, Results obtained with a Thermograph for Surface Temperatures during the "Snellius" Expedition. Journ. du Conseil, Vol. VIII, No. 1, S. 64 ff. Kopenhagen, 1933.

regionalen Verteilung des Oberflächensalzgehaltes in den Expeditionsgewässern. Visser hat dazu alles erreichbare zuverlässige Material herangezogen, u. a. auch die verdienstvollen Sammlungen K. M. van Weels. Diese neueste Darstellung bestätigt wieder generell die früheren Versuche und Ergebnisse, verbessert sie aber in nicht wenigen Punkten. Der Einfluss der Landnähe, der Monsunregen und der mit den Monsunen wechselnden Oberflächenströmungen wird ersichtlich. Die eingezeichneten Isohalinen gehen, mit einer einzigen Ausnahme, nirgends über 34·5 $^0/_{00}$ hinaus, was sich natürlich damit verträgt, dass gleichwohl in Einzelfällen etwas höhere Salzgehalte beobachtet worden sind.

G. Schott.

Nachschrift. In der zwischen der Einsendung und der Drucklegung des vorstehenden Referates vergangenen Zeit erschien die Untersuchung von A. Defant und H. Ertel: "Durch Niederschläge verursachte Störungen des Salzgehaltes im Ozean und deren Ausgleich durch Turbulenz". (Abhandlung Preuss. Akad. d. Wissensch. 1939, Nr. 10). Weil das theoretische Ergebnis dieser Untersuchung nur mit sehr wenigen tatsächlichen Beobachtungen verglichen werden konnte, möchte ich erwähnen, dass Visser an der Hand des ihm zur Verfügung stehenden Materials dies Problem auf S. 24 auch erörtert. In der zentralen Celebes-See hatte er im SE.-Monsun inselartige und beträchtliche Erniedrigungen des Salzgehaltes erhalten, die er mit den starken Regen des Juni 1930 auf "Snellius" in Beziehung setzt, Visser meint, dass man — nach seinem Material — etwa 0·6 $^0/_{00}$ Salzabnahme durch die Regen ansetzen dürfe. Jedenfalls ist ganz allgemein beim Zeichnen von Isohalinen Vorsicht geboten, sofern eine lokale und zeitlich beschränkte Salzminderung auftaucht.

11. 10. 39. *G. Sch.*

E. Goedecke. "Beitrag zur Hydrographie der Helgoland umgebenden Gewässer. I. Die Oberflächenverhältnisse bei Helgoland-Reede. II. Die mittleren hydrographischen Verhältnisse bei den Helgoländer Terminstationen." Ann. der Hydr. usw., LXVII. Jahrg., H. IV u. V, S. 161—176, 12 Abb.: S. 224—234, 6 Abb. Berlin, 1939.

The material for this research into the hydrographic conditions near Helgoland consists of a series of 10 years of observations in Helgoland Roads and at 4 fixed stations. In Helgoland Roads the observations were taken 4 times a month until 1929, and since then, as on the German lightships, on each day of spring tide, mean tide or neap tide at two successive moments of shifting of the tidal current. The position of the fixed stations is given by a table of co-ordinates and shown in Fig. 1 and on a transparent sheet on the same scale as a depth chart of the surroundings of Helgoland, the depth at these stations varying between about 12 and 44 m. Particular features on the depth chart are a ridge at a depth of about 20 m. east of Helgoland, and a trough of over 55 m. south of Helgoland. The author proposes revised positions of the fixed stations in order to represent better the depth conditions.

The extreme monthly values for temperature in Helgoland Roads as compared with former values are:—

	Aug.	Febr.
1873—1893	16·9° C.	2·7° C.
1893—1907	16·2° C.	2·6° C.
1927—1936	17·0° C.	3·4° C.

The salinity shows a maximum of 33·0 ‰ in January and a minimum of 31·4 ‰ in May. This minimum, caused by the large flood from the rivers in spring, occurs here a month later than at the lightships nearer the shore.

Fig. 8 gives a representation of the monthly means and the absolute maxima and minima of salinity in each month, showing that the accidental variations are much bigger than the seasonal ones. Especially in spring the alternating penetration of Atlantic and river water causes fluctuations up to 6 ‰.

The observations at the beginning and the end of tides since 1929 enabled the author to calculate the influence of the tides on salinity: —

	Spring tide	Mean tide	Neap tide
High tide	32·35 ‰	32·23 ‰	32·29 ‰
Low tide	32·34	32·23	32·11
Diff.	0·01	0·00	0·18

Hence only at neap tides is there an appreciable difference, and also the differences between the various types of tide remain of the order of 0·1 ‰. Larger differences appear when the frequency of various salinities is calculated. The percentage frequency appears then to be, for example,

	Salinity 29·5—30·0	32·0—32·5	34·0—34·5
Neap tides	4 %	15 %	1 %
Mean tides	2	18	2
Spring tides	0	23	3

The difference between high and low tide, calculated monthly irrespective of the type of tide, varies from —0·02 (winter) to +0·11 (June). The mean absolute differences show a maximum of 0·31 in April and a minimum of 0·11 in January. Differences over 1·00 ‰ did not occur during July—September or December.

The author then discusses the various difficulties inherent in the determination of the flood of the Elbe and Weser, and warns against too far-going conclusions from the apparant relation between flood and salinity; the opposition of their fluctuation was mentioned above. Several graphs and tables illustrate the figures discussed.

In the second paper, the mean hydrographic conditions at the fixed stations are analysed. Serial observations have been taken here twice a month, and have been reduced to half-monthly means.

The yearly range at the surface, 14·4°—14·7°, is about 1·0° C. higher than in Helgoland Roads and the maximum nearly equal at all four stations. Below the surface, observations have been taken near the bottom (22—44 m.) and at an intermediate depth (10—20 m.). Table 1 shows that the maxima and minima occur in the same half-month as at the surface, but at the deeper stations one or two half-months later. There is very little difference between the mean temperatures of the intermediate and bottom layers; the intermediate layer is 0·2°—0·5° C. colder than the surface. The amplitude decreases near the bottom by 0·7—1·2° C. From April to July, the deeper layers are colder; in January and February the reverse is the case.

With few exceptions, the salinity is higher in the deeper layers, especially in spring when the surface shows a minimum not present in the bottom layers. This difference is most strongly pronounced at stations IIa and IV, where it exceeds 2·5 ‰ in May. At the first station, to the west, the

difference is ascribed to an undercurrent of cold, salt water; at station IV, to the east, overflow of water mixed with river water, which is also heated quicker in spring, causes the higher salinity and lower temperature at the bottom. These two masses of water form a convergence, which shows large fluctuations in its position from day to day.

The yearly range of salinity is much smaller in the deeper layers; for example at station I it decreases from 3·26 at the surface to 1·26 at the bottom. The time of maximum is January for all stations and depths, with the exception of the bottom layer at station IV where it occurs in March and April, and station IIa, where at 20 m. a secondary maximum occurs in March and the principal maximum at the bottom in April. The minimum, which occurs at the surface from February to June, is found near the bottom in the second half of October.

These deviations cause a stratification in spring, most strongly pronounced in the salinity, where it is partly maintained in winter, whereas for temperature in winter almost complete uniformity is attained through mixing.

Many figures illustrate these particulars.

van E.

A. C. Redfield, H. P. Smith and **B. Ketchum.** "The Cycle of Organic Phosphorus in the Gulf of Maine." Biol. Bull., Vol. LXXIII, No. 3, pp. 421—443, 4 figs. Woods Hole, Mass., 1937.

How much of the story of phosphorus in the sea do determinations of inorganic or ionic phosphorus tell us? The demand for an answer becomes the more pressing as we improve the accuracy of our analyses and attempt to deduce important long-period fluctuations in the planktonic population from quite small variations of a single constituent. The delay has been occasioned by the lack of methods able to give with certainty and expedition a measure of particulate and organic phosphorus. The present authors seem to have produced the most satisfactory solution yet.

The difficulty in particulate phosphorus determinations have been less of analysis than of sampling. Separation of all the planktonic and particulate phosphorus has now been cleanly achieved by sucking a water sample (300 ml.) through a precipitate of barium sulphate held on a sintered glass filter (3G4). The rest of the analysis may then be readily achieved by a refinement of existing methods.

In the more rapid methods which have been used for total phosphorus, sea water has been treated directly with oxidizing agents. It has become increasingly doubtful how far such methods destroy all organic matter or oxidize trivalent to quinquevalent arsenic. To resolve this uncertainty evaporation with concentrated sulphuric acid and treatment with hydrogen peroxide was thought necessary. Since quinquevalent arsenic behaves as phosphorus in the Denigès-Atkins test, removal is desirable. Here again at these very high dilutions only drastic methods avail. The end is achieved by heating the oxidized sample with acidified sulphite in a stoppered bottle on the steam bath for eight hours. The method has been applied for total phosphorus in all forms and for total dissolved organic and inorganic phosphorus after removal of the particulate fraction. Exemplary attention to detail has been paid and although the methods demand considerably more of the analyst than do determinations of inorganic phosphorus, the way to further knowledge of the phosphorus cycle has been well laid.

During the twelve months May 1935—May 1936, five stations were worked from the "Atlantis" at practically the same spot in the Gulf of

Maine. Inorganic phosphate represented by far the greater part of the phosphorus in the water column as a whole, ranging from 72 to 92 % at different times. It is rather uniformly distributed throughout the year at depths greater than 80—100 m., but increasing somewhat with depth. As elsewhere inorganic phosphate in the superficial layers was reduced during spring and restored during the winter.

Particulate organic phosphorus, representing organisms and detritus, is in general the smallest of the three fractions — about 5 % of the total being greatest in the top 40 m. and in spring, as might be expected. Below the photosynthetic zone the particulate organic phophorus was surprisingly uniform as regards both depth and season.

Dissolved organic phosphorus appeared to be at a minimum in early spring and began to occur at the surface in May, working downwards through the water column as the summer and autumn advanced. Not until November were high concentrations observed near the bottom. Work in Great Britain has shown that the winter maximum of inorganic phosphate, reached usually in early January, may be correlated with the subsequent production of plankton indicators and of summer spawning young fish and with the direction of flow of water through the Straits of Dover. These relations might be invalidated if any considerable quantity of organic phosphorus were present at that time, so augmenting to an unknown degree the stock of phosphorus available for the production of the following season's plankton production. Fortunately the Woods Hole data suggest that the picture is unlikely to be upset in this way.

Further analysis of the data is made as a series of balance sheets showing the exchanges of the different forms of phosphorus during the year. Certain necessary assumptions appear, in our present state of knowledge, to be justified but need constantly to be borne in mind. Without setting these out in detail the conclusions may not be fairly summarized. It must suffice to say that the vertical transport of phosphorus compounds within the water mass demanded by the analysis may reasonably be accounted for by the hydrographic conditions obtaining and are concordant with such other studies of the changes in these constituents as have been made. The balance sheet method is one which could be applied with profit wherever sufficient data may be found in a situation having suitable hydrographic uniformity. This paper is likely to become a classic and will need consideration in any full study of the phosphorus cycle in the sea.

L. H. N. C.

T. Braarud and **J. T. Ruud.** "The Hydrographic Conditions and Aeration of the Oslo Fjord, 1933—1934." Hvalrådets Skr. Nr. 15, pp. 56, 24 figs. Oslo, 1937.

The authors consider hydrographical and chemical data collected on seven cruises in the Oslo Fjord from June 1933 to May 1934. Observations were made on salinity distribution, temperature, and content of oxygen, phosphates, and phytoplankton. Concerning the standard Winkler method of determining oxygen, the authors cite A l s t e r b e r g as having concluded that the presence of organic matter results in too-low values being obtained.

The origin of Oslo Fjord is here ascribed to block-faulting along N.-S. lines and to glaciation. There are within it deep basins, shallow banks, and closed branches isolated by high sills. About a quarter of the way down the fjord from Oslo there is a narrow and shallow strait, Drøbak Sound,

where there is a bar carrying only 40 metres of water. The "inner fjord" to the north (containing depths of as much as 160 metres) receives very much less land drainage water than does the "outer fjord" to the south. There can be no direct exchange of deep water between those two parts of the fjord, yet the deep water of the inner part can undergo renewal (be "aerated"), as is very thoroughly explained. The authors give an adequate summary of previous relevant work, and a very useful exposé of the way in which oxygen content usually varies with depth by reason of photosynthesis and atmospheric contribution in the upper layers, and consumption in the layers beneath. But for renewal of the deep water in the inner fjord, there would be absence of oxygen. They cite the case of one branch of the inner fjord (the Drams Fjord) where, owing to a sill carrying only 6 metres of water, the water below 20 metres contains H_2S and practically no oxygen is to be found. This state of affairs resembles those in certain Swedish fjords and to some extent in the Black Sea.

Hjort and Gran had earlier declared that the renewal of the deep waters of the inner basin of Oslo Fjord takes place at irregular intervals, and that any influx of new water into the deeps north of the Drøbak shallows was mainly governed by wind. It was observed that northerly winds could force out the surface waters from the inner fjord, and so cause deep water to come to the top. They apparently *assumed* that compensating currents were thereby drawn in at the bottom. In the present report, Braarud and Ruud study the water exchange processes with special regard to the frequency with which "aeration" took place. They say what conditions most usually exist each side of the Drøbak bar in point of salinity, oxygen content, and phosphate content variation with depth, and state what changes would reveal the occurrence of an influx of new deep water into the inner fjord. Wind data (observations every other hour) from Ås, near Drøbak, are put into the form of N.-S. component values summed for each day. For each of twelve months these wind component values are plotted in histogram form, and against them are graphed data giving depth of water in Oslo harbour. It is seen that southerly winds dam the water up in the northern end of the fjord, while a strong northerly component in the wind lowers the depth of water.

Much attention is paid to salinity conditions at 1 metre depth on the opposite sides of Drøbak Sound. The lowest salinities may be found in the inner fjord, they may occur in the outer fjord, or the surface layer salinity may be materially the same on both sides of Drøbak bar. The lowest salinities are found in the outer fjord when northerly winds have carried the surface waters out of the inner basin and have caused the deeper and more salt layers to rise there. A compensating influx of water then takes place across the bar into the deep layers of the inner basin, the inflowing water being rich in oxygen and poor in phosphates compared with that replaced. If the deep water in the inner fjord has been renewed, then, on going down to the deepest water strata (the "new") through the intermediate strata (the "old" deep water), a decrease in phosphate content and an increase in oxygen content will be observed. These influxes and their dependence on northerly winds are very clearly shown in a table. The power of the wind to bring about such horizontal water movements through Drøbak Sound as can effect renewal of the deep water in the inner fjord is of particular interest to those readers who attach great importance to the rôle played by the wind in the open sea.

The authors refer to the effect upon aeration of sewage discharge into the fjord (to be the subject of a future paper) and of a jetty which stretches across the western limb of the inner fjord just north of Drøbak Sound. They show that both act "to produce less well-aerated waters in the inner basin"

Messrs. Braarud and Ruud have presented their results in a report in which the reviewer has noticed no obscurities, and there would seem to be no points about which controversy could arise. *J. N. Carruthers.*

C.-G. Rossby. "On the mutual adjustment of pressure and velocity distributions in certain simple current systems. I and II." Journ. Mar. Research, Vol. I, pp. 15—28, figs. 5—9: No. 3, pp. 239—263, figs. 84—87. New Haven, Conn., 1937 and 1938.

C.-G. Rossby und seine Schule haben sich zur Aufgabe gestellt zu untersuchen, auf welche Weise sich die bei stationären Zuständen vorhandene Beziehung zwischen Massen- und Stromfeld ausbildet, wenn dieser dynamische Gleichgewichtszustand zuerst nicht vorhanden ist und sich erst allmählich entwickelt. Das Problem hat eine grosse Bedeutung für Fragen, die die unperiodischen Störungen im Meere betreffen, sei es, dass man zu wissen wünscht, auf welchem Wege und in welcher Zeit vorgegebene Störungen sich ausgleichen und in einem schliesslichen Gleichgewichtszustand aufgehen, sei es dass man wissen möchte, wie tief oberflächliche Störungen hinabreichen und wie die tieferen ozeanischen Schichten darauf reagieren. Rossby hofft, durch schrittweise Lösung gewisser einfacher Teilprobleme schliesslich eine endgültige Antwort auf die oben gestellten Fragen zu geben.

In der ersten Arbeit untersucht er die Bedeutung der seitlichen Vermischungs- (Turbulenz) Prozesse im Falle, dass eine geradlinige Strömung in ein homogenes, inkompressibles Medium, das einer Rotation um eine senkrechte Achse unterliegt, freistrahlartig eindringt und sich unter Beibehaltung seines Bewegungsmomentes weiter ausbreitet. Das Hauptresultat der theoretischen Durcharbeitung der Aufgabe ist, dass sich auf beiden Seiten des Hauptstromes Gegenströme ausbilden, deren Intensität etwa 11 % der Geschwindigkeit im Hauptstromstrich erreicht. An der Oberfläche des Meeres begleitet den Abfall des Meeresniveau des Hauptstromes links eine Rinne niedrigen, rechts ein Rücken hohen Wasserstandes, wodurch der Abfall quer zur Strömung um etwa 8 % vergrössert wird. Die seitliche Vermischung hat demnach die Wirkung, die Massenanhäufung rechts zu verstärken und gleichzeitig im umgebenden Medium schwache Gegenströme zu erzwingen.

In der zweiten Arbeit behandelt Rossby die Frage, wie bei einem mehr oder minder plötzlich durch äussere Einwirkung (Wind) in einem Meeresstreifen entstandenen Gradientstrom das Massenfeld sich dem Stromfeld anpasst, zunächst unter Ausschluss jeglicher seitlicher Vermischung. Die Analyse dieses Problems wird für ein homogenes, für ein zweifach geschichtetes Meer und schliesslich auch für ein unter einer homogenen Deckschicht stabil geschichtetes Meer durchgeführt. Der erste Fall ist relativ einfach. Die Schiefstellung des Meeresniveau begleitet rechts eine Erhebung, links eine Senkung des Meeresspiegels, die an schwache Gegenströme geknüpft sind. Die Einstellung der Massenverteilung zum Stromfeld erfolgt allmählich und ein kleiner Teil der verfügbaren Energie wird in Trägheitsschwingungen um die schliessliche Gleichgewichtslage verbraucht. Der zweite Fall eines zweifach geschichteten Meeres ist noch einfach, solange die Annahme gemacht wird, dass in den unteren homogenen Wassermassen die Wasserbewegungen vernachlässigbar sind. Die innere Grenzfläche zwischen beiden Wasserarten muss

sich dann ebenfalls schiefstellen, aber in entgegengesetzter Richtung wie die Oberfläche und in einem im Verhältnis zum Dichteunterschied verstärktem Masse. Ausserdem kommt es wieder zu Gegenströmen auf beiden Seiten des Hauptstromes. Die Lösung ist plausibel, auch dass in diesem Falle die Gegenströme stärker und die in Trägheitsschwingungen übergehende Energie grösser sein werden. Aber das von Rossby zahlenmässig errechnete Beispiel lässt doch Bedenken aufkommen, ob wohl alles richtig ist. Denn dass die Gegenströme an Energie vielmals stärker werden als der Hauptstrom, und dass 89 % der verfügbaren Energie in Trägheitsschwingungen erscheint, ist wohl kaum vorstellbar.

Der Fall, in dem auch die Massenverschiebungen in der Unterschicht zur Berücksichtigung kommen, ist schon schwieriger, noch mehr der Fall homogene Deckschicht + stabilgelagerte Unterschicht, der nur eine Lösung unter der Annahme findet, dass jede isopyknische Schicht der Untermasse ihre absolute Wirbelstärke (vorticity) beibehält. Diese letzteren Fälle sind von besonderem Interesse, weil sie eine Antwort auf die Frage erwarten lassen, inwieweit eine Druckstörung in der Oberschicht in die Unterschicht übergreift, und inwieweit durch Bildung eines Solenoidfeldes in der stabil geschichteten Unterschicht der Störung von oben entgegengewirkt wird. Die Antwort, die Rossby gibt, lässt erwarten, dass Störungen der Oberfläche noch in den tiefsten Meeresschichten sich in einem in keiner Weise vernachlässigbaren Betrage bemerkbar machen. Das Mass für dieses Durchgreifen hängt aber von den Dimensionen (Oberflächenausdehnung) der Druckstörung ab. Von Störungen an der Oberfläche von nur wenigen Kilometern Ausdehnung wird man am Boden einer geschichteten Untermasse (etwa 1800 m.) kaum etwas merken; wenn aber die Störung 200 km. und mehr beträgt, kann sich noch die Hälfte der Störung am Boden zeigen. Das Resultat würde bedeuten, dass sich die unperiodischen Oberflächenstörungen der gemässigten Breiten nicht auf die Oberflächenschicht allein beschränken, sondern auch die tieferen Schichten beeinflussen können und sich in den Messungen der ozeanographischen Stationen zeigen müssen. Rossby meint, dass dieses wichtige Ergebnis die Auffassungen über die ozeanische Zirkulation der tieferen Schichten zu beeinträchtigen vermögen könnte. Wenn man die aus stetig wirkenden Kräften resultierenden stationären Bewegungen — und nur diese fasst man unter den Begriff "ozeanische Zirkulation" zusammen — betrachtet, dann dürfte diese Meinung Rossbys nur in beschränktem Masse zutreffen.

A. Defant.

G. F. McEwen. "Some energy relations between the sea surface and the atmosphere." Journ. Mar. Research, Vol. I, No. 3, pp. 217—238, figs. 82—83. New Haven, Conn., 1938.

Die Untersuchung McEwens betrifft das komplizierte Zusammenspiel der Prozesse der Strahlung, der Konvektion und Verdunstung in der Nähe der Meeresoberfläche, das im wesentlichen den Wärmeaustausch zwischen Ozean und Atmosphäre regelt und die meridionale Oberflächenverteilung der Temperatur festlegt. Da der Wärmegewinn eines Volumelementes an der Meeresoberfläche durch Absorption der eindringenden Sonnenstrahlung durch den gesamten Wärmeverlust durch Konvektion, Ausstrahlung und Verdunstung bei stationären Verhältnissen kompensiert werden muss, erhält man eine einfache Differentialgleichung, deren Lösung die tatsächliche Verteilung der Temperatur des Wassers in Abhängigkeit von der Zeit, der geographischen Breite und der Tiefe (bis etwa 35 m.) gibt. Zur Prüfung der theoretischen

Formeln, deren Konstanten aus den physikalischen Messungen zahlenmässig ermittelt wurden, an der Erfahrung zieht McEwen die 20-jährigen Temperaturbeobachtungen der Fünfgradfelder zwischen 20° und 50° N. Br. im östlichen Nordpazifischen Ozean (bearbeitet vom Japanischen Observatorium zu Kobe) heran und benützt für die Strahlungsmengen, die die Meeresoberfläche erreichen, die von H. H. Kimbal (U. S. Weather Bureau) angegebenen Werte. Die obigen Temperaturbeobachtungen sind für eine solche Untersuchung deshalb besonders geeignet, weil sie ein Gebiet betreffen, das durch Meeresströmungen nur wenig beeinflusst sein dürfte. In der Tat stimmt der theoretische Jahresgang der Temperatur für die verschiedenen Breiten recht gut mit dem beobachteten überein. Die theoretischen Überlegungen McEwens gestatten auch, den Anteil des Wärmeverlustes zu bestimmen, der auf Kosten der Verdunstung geht. Dies führt gleichzeitig dazu, die mittlere jährliche Verdunstungsmenge in Abhängigkeit von der Breite zu ermitteln, die mit den von Wüst, Cherubin und Sverdrup durch Reduktion der Schiffsbeobachtungen erhaltenen Zahlenwerte gut übereinstimmen. Die Untersuchung McEwens ist die erste, die in befriedigender und in physikalisch einwandfreier Weise, allerdings, wie nicht anders möglich, mit einigen Vereinfachungen, die meridionale Verteilung der Temperatur der Meeresoberfläche quantitativ zu erklären vermag.

A. Defant.

H. R. Seiwell. "Application of the Distribution of Oxygen to the Physical Oceanography of the Caribbean Sea Region." Pap. in Phys. Oceanogr. and Meteor., Vol. VI, No. 1, pp. 60, 42 figs. Cambridge and Woods Hole (Mass.), 1938.

Das umfangreiche Sauerstoff-Beobachtungsmaterial der beiden "Atlantis"-Fahrten März bis Mai 1933 und Februar bis März 1934 in das Karibische und Yukatan-Meer findet eine systematische Bearbeitung. Das Schwergewicht der Arbeit liegt auf der Festigung der Vorstellung der physikalischen Vorgänge von Ausbreitung und Vermischung aus der Verteilung des Sauerstoffs. Die regionale Sauerstoffverteilung wird durch eine kurze und übersichtliche Darstellung vermittelt, indem 9 Profile der "Atlantis" in Vertikalschnitten wiedergegeben werden und die horizontale Verteilung unter Einbeziehung des östlichen Golfs von Mexiko in folgenden Horizonten dargestellt wird:— 100, 250, 500, 750, 1000, 1500, 2500, und 3500 m. Ausserdem wird eine Karte der Verteilung des Sauerstoffs in der Tiefe des O_2-Minimums gegeben. Der eindeutigen Zweiteilung in einen geschichteten Teil oberhalb der Satteltiefen und in einen nahezu gleichförmigen Wasserkörper unterhalb der Satteltiefen sind Methoden und Diskussionen angepasst. Für die oberen Schichten erweist sich die Beziehung Sauerstoff-/Salzgehalt sehr fruchtbar; denn die Einbeziehung der varianten Eigenschaft (wenn man von der Mischung absieht) erlaubt noch eine Trennung kleinerer regionaler Unterschiede in den Wasserkörpern, wo die $S = f(t)$-Darstellung nur auf Gleichförmigkeit schliessen lässt. An der $O_2 = f(t)$-Beziehung konnte der Wert einer Verwendung des Sauerstoffes zur Charakterisierung von Wasserkörpern bereits nachgewiesen werden (G. Dietrich. "Über Bewegung und Herkunft des Golfstromwassers." Veröff. Inst. f. Meereskunde, N. F., R. A., Heft 33, 1937). Durch die Zunahme des Sauerstoffs nördlich der Antillen von Ost nach West erhält die Windward-Passage von allen Durchlässen zwischen den Antillen den sauerstoffreichsten Einstrom. Die südliche Komponente in der Ausbreitung wird dadurch besonders hervorgehoben; ähnliches gilt für die

Verteilung des Salzgehaltes im Kern des Salzgehalts-Minimums. In diesen Fällen erscheint bei den Schlüssen aus der Verteilung der Eigenschaften Vorsicht am Platze, da selbst kleinere meridionale Injektionen mit wesentlich anderen Eigenschaften die zonale Ausbreitung stark überdecken können.

Die Zunahme des Sauerstoffs nördlich der Antillen gegen Westen bleibt auch in grösseren Tiefen bestehen, sodass im Niveau der Satteltiefen beim gleichen Salzgehalt vor der Windward-Passage höhere Sauerstoffwerte anzutreffen sind als vor der Anegada-Jungfern-Passage. Es braucht darum nicht zu verwundern, wenn das Yukatan-Becken in der Tiefe etwa 0·5 cm.^{3}/l. reicher an Sauerstoff ist als das Karibische Becken. Beide Passagen erkennt Seiwell ebenso wie Parr (Bull. Bingham Oc. Coll., Vol. V, Art. 4, 1937) als massgebend für die Erneuerung des Tiefenwassers des Amerikanischen Mittelmeeres. Man braucht aber keine 2500 bis 3000 m. als Satteltiefen für die Windward-Passage und etwa 2000 m. für die Anegada-Jungfern-Passage anzunehmen, wie es Seiwell tut, Werte, die abgesehen von den thermischen Verhältnissen auch schwerlich mit den Lotungen in den Strassen vereinbar sind. Die Kritik an der Brauchbarkeit der potentiellen Temperatur zur Bestimmung der Satteltiefen erscheint nicht haltbar. Letztere Methode ergab für die Satteltiefen der Anegada-Jungfern-Passage 1600 bis 1620 m., für die Windward-Passage 1600 m. in Übereinstimmung mit der Sauerstoffverteilung (G. Dietrich, Ann. d. Hydr. *65*, 1937).

An die Bearbeitung der Ausbreitung knüpfen einzelne Fragen an, so die Beziehung des Sauerstoff- zum Salzgehaltsminimum und des Sauerstoffminimums zur Dichte. Das O_2-Minimum wird bei $27{\cdot}171 \pm 0{\cdot}007\ \sigma_t$ errechnet. Die Untersuchung von vertikalem und horizontalem Austausch an zwei Stationen des Karibischen Meeres wurde in dieser Zeitschrift bereits abgedruckt. (Journ. du Cons., *13*, 155, 1938).

Die Arbeit kann als ein eindrucksvoller Beweis betrachtet werden, wie aus einer geeigneten Darstellung des Sauerstoffes die Bewegungsvorstellungen vertieft und gestützt werden können, die mit physikalischen Methoden erschlossen wurden.

G. Dietrich.

R. B. Montgomery. "Circulation in Upper Layers of Southern North Atlantic deduced with use of Isentropic Analysis." Pap. in Phys. Oceanogr. and Meteor., Vol. VI, No. 2, pp. 55, 10 figs., charts 19. Cambridge and Woods Hole (Mass.), 1938.

Die isentropische Analyse, die von N. Shaw 1930 in die Meteorologie eingeführt wurde und seitdem durch C. G. Rossby Vertiefung und Ausbau erfuhr, findet in dieser Arbeit eine erste systematische Anwendung auf eine ganze ozeanische Region. Unter isentropischer Analyse im Ozean versteht man die Darstellung der hydrographischen Eigenschaften des Wassers auf einer Fläche gleicher potentieller Dichte. Grundvoraussetzung ist, dass die Bewegungen vollkommen parallel zu diesen Flächen erfolgen, das heisst keine vertikale Mischung und keine Strahlung wirksam sind. Damit ist die Methode von vornherein nur im stark geschichteten Bereich der Ozeane anwendbar, also in der ozeanischen Troposphäre unterhalb der homogenen Deckschicht und oberhalb der schwach geschichteten Stratosphäre. Auch innerhalb der Troposphäre scheiden Mischungszonen aus, wie die Zone vor der Strasse von Gibraltar und das westafrikanische Auftriebsgebiet, ausserdem Flachwassergebiete im Wirkungsbereich der Bodenreibung. Dagegen wird die isentropische

Analyse durch seitliche Vermischung nicht beeinflusst, solange diese Vorgänge keine Dichteänderung mit sich bringen.

Streng genommen müssten der Analyse potentielle Dichteflächen zu Grunde gelegt werden. Aber Montgomery zeigt, dass der adiabatische Effekt für den praktischen Zweck vernachlässigt werden kann, und es genügt, σ_t-Flächen zu verwenden. Die Ergebnisse der Stromvorstellungen sind nur qualitativer Natur. Zwei Vorzüge der isentropischen Analyse seien besonders betont. Die Methode ist unabhängig von den Störungen des Aufbaus durch interne Wellen, und man ist gegenüber der ebenfalls qualitativen Kernschichtmethode nicht an vereinzelte markante Eigenschaften gebunden. Es stehen beliebig viele σ_t-Flächen zur Verfügung.

Mit der neuartigen, darum etwas ausführlicher referierten Methode wird der Nordatlantische Ozean zwischen 0°—30° N. untersucht. Übersichtlich werden Karten der Salzgehalts- und Sauerstoffverteilung auf den Dichteflächen 27·0, 26·5, 26·0, 25·5, 25·0 und 24·0 σ_t gegeben mit den dazugehörigen Karten der Tiefenlagen. Auf 10° N. werden zum Beispiel damit Schichten zwischen 400—50 m. erfasst. Besonderes Gewicht erhält die Methode im troposphärischen Salzgehaltsmaximum, da hier die Sprungschicht praktisch zur Sperrschicht ausgebildet ist. Montgomery berechnet später (Ann. d. Hydr., Bd. 67, 242, 1939) den vertikalen Austauschkoeffizienten in dieser Schicht zu maximal 0·4, im einzelnen kann er bis zum molekularen Diffusionskoeffizienten 0·011 $cm.^{-1}$ g. $sec.^{-1}$ absinken.

Indem Montgomery in die Salz- und Sauerstoffzungen die Stromzweige legt, gelangt er zu einem vielgliedrigen Stromsystem. In der Schicht des Salzgehaltsmaximums, in der eine Vergleichsmöglichkeit mit den Ergebnissen von A. Defant besteht, zeigen beide Stromdarstellungen in einzelnen Teilen Widersprüche. Es ist ohne weiteres nicht abzumessen, wie weit methodische und wie weit darstellungsmässige Gründe dazu geführt haben. Eines fällt an den Karten auf, nämlich wie die einfachen Züge des Stromsystems innerhalb der Sperrschicht σ_t: 25—26 nach unten mit dem abnehmenden Dichtegradienten komplizierter werden. Vielleicht sind an dieser Erscheinung vertikale Mischungsvorgänge bereits massgebend beteiligt.

Die qualitativen Ergebnisse der Analyse werden in einem besonderen Abschnitt durch die dynamische Berechnung des "Atlantis"-Schnittes längs 40° W. von 3°—29° N. ergänzt, der aber nur im Süden im Bereich des Gegenstromes und des Nordäquatorialstromes Gewicht beigelegt wird. Eingeschaltete Richtungswechsel der berechneten Zonalkomponenten werden auf Störungen durch interne Wellen zurückgeführt.

In einem weiteren Abschnitt wird zu früheren Untersuchungen Stellung genommen, besonders zu der von A. Defant. Andere interessante Gedanken der Arbeit konnten hier nicht einmal gestreift werden. Sie verdienen aber neben dem methodisch wichtigen Fortschritt in der isentropischen Analyse volle Beachtung der Ozeanographen.

G. Dietrich.

G. Granqvist. "Zur Kenntnis der Temperatur und des Salzgehaltes des Baltischen Meeres an den Küsten Finnlands." Havsforskningsinst. Skr., No. 122, S. 1—166, I—XXXII, Fig. 90, Taf. III. Helsingfors, 1938.

As is well known, Finland has contributed largely to the hydrographic exploration of the northern part of the Baltic, especially after the foundation of *Havsforskningsinstitutet* in 1919. In the present work Granqvist has endeavoured to compress the comprehensive collection of observations into a "normal" picture of temperature and salinity conditions.

The observations of temperature and salinity used by the author comprise:

1) observations on the 1st, 11th, and 21st of each month throughout the year at various depths at 22 fixed stations during the years 1921—1930;

2) observations on the 1st, 11th, and 21st of each month during the summer at various depths at 10 fixed "summer stations" during the years 1921—1930,

3) observations in May, July, November and February made at 66 fixed places at sea on research-cruises.

From the observations under item 1) ten-year means of temperature and salinity for each day of observation have been calculated for each depth at each station, and the series of 36 means thus computed were smoothed by harmonic analysis according to the formula $v = m + a \cos(\alpha - t) + b \cos 2(\beta - t) + c \cos 3(\gamma - t)$. Tables of the computed harmonic constants are given, and for each of the 22 stations a diagram shows the harmonically smoothed curve of seasonal variation of temperature and salinity at each depth of observation. In an appendix is also given the harmonically computed values of temperature and salinity on the 1st, the 11th and the 21st of each month.

From the observations under item 2) ten-year means of temperature and salinity for each day of observation during the working season of the station were calculated and the mean values were smoothed according to the formula $m = \frac{a+2b+c}{4}$.

The smoothed mean values of temperature and salinity on the 1st, 11th, and 21st of each month of observation are given in a table and also reproduced graphically.

The observations under item 3) are not nearly so comprehensive as those under items 1) and 2), notwithstanding that in this case all observations available have been considered, and therefore simple mean values only have been calculated. These are given in a table.

For each of the 66 high-sea stations mean t—S curves for May, July, November, and February have been drawn and arranged in three diagrams corresponding to the following areas: Gulf of Bothnia, the Baltic and the Gulf of Finland. These diagrams also contain corresponding t—S curves for the fixed stations. These diagrams, which further show the curves of equal density, display a very clear picture of the temperature-salinity conditions. Supplemented by other t—S diagrams showing the variation of the t—S curves month by month they form an excellent basis for the discussion of the seasonal variation of the hydrographic conditions, of which the most conspicuous features are the homogenization of the water layers in autumn and winter and the formation of the surface layer during the summer.

Granqvist's work contains an abundance of detail into which we cannot enter here. I will confine myself to mention of a chapter dealing with observations 6 times daily from the light-vessel "Äransgrund" during 3 weeks of July, 1914. These observations show that significant alterations of short duration, which are well known from other places, also take place in the Gulf of Finland, and the author emphasizes the importance of methodical simultaneous observations from more points within the same area, if a true picture of the hydrographic conditions within the area is to be obtained.

A great amount of work is deposited in this book which supplies an

excellent exposition of the "normal" temperature and salinity conditions of the waters concerned.

Helge Thomsen.

E. Goedecke. "Die Temperatur- und Salzgehaltsanomalien des Oberflächenwassers der Deutschen Bucht auf Grund der deutschen Feuerschiffsbeobachtungen 1923—1936." Ber. Deutsch. wiss. Komm. f. Meeresf., N.F., Bd. 9, H. 2, S. 254—261, 2 Abb. Leipzig, 1939.

Various authors have referred to extremely high values of salinity and temperature in the northerly parts of the North Sea, reaching a maximum in 1935, caused probably by an increase of the influx of Atlantic water from the north between the Shetlands and Norway. The deviations from the means for 1923/32 for the German lightships, and for 1927/36 for Helgoland Roads show similar features. With few exceptions, the deviations for the various stations are in the same direction; here, however, it is the year 1934 which shows the greatest number of deviations in temperature over 1·0° C. For salinity, the deviations show maximum values during 1933/35, rising to 4·55 $^0/_{00}$ for "Elbe 4" in 1934; for Helgoland Roads, the maximum deviation is shown as early as 1930.

It appears that these maxima of temperature and salinity coincide generally with minima in the flood (outflow) in the Elbe and Weser. From the following papers referred it appears that the author doubts the validity of the conclusion that the maxima of salinity at least are caused by the decreased influence of river water. As he shows that the deviations in temperature are caused especially by high winter values, and river water is colder than sea water in winter, decrease in river water would here also lead to increased temperatures. Tables 3 and 4 and Fig. 1 illustrate these correlations.

The author, however, looks for a common explanation of the various deviations in the general circulation and continental influences. He cites Zedler's figures in order to show that the precipitation on Brocken and Schneekoppe diminished gradually from 1896 to 1930, but this table shows for the Brocken, maximum 1900/09, minimum 1916/25, for the Schneekoppe, maximum 1907/16, minimum 1899/08! The conclusion that increased continental influences are among the causes of the deviations in temperature and salinity is not very convincing. He further refers to Scherhag's researches into an increase in the atmospheric circulation in the northern hemisphere, evident from the decrease of glaciation in the arctic regions and the increase of surface temperature of the water in arctic and temperate regions, according to the author's investigations shown also by a deepening of the 0° isotherm in the Barentz Sea from 150 m. to 260 m. in October 1937. Certainly the fact that marked positive deviations from the mean for 42 years are also shown during 1932/36 for Selvogsbank near Iceland points to a common cause in radiation or circulation. On the other hand, a comparison of these deviations with those for "Borkumriff" and the English Channel according to Lumby shows about as many contradictions as correspondencies; the author sees periodicities of 5, afterwards 7, years in the contradictions.

van E.

N. G. Johnson and **G. Liljequist.** "On the Angular Distribution of Submarine Daylight and on the Total Submarine Illumination." Svenska Hydrogr.-Biol. Komm. Skr., N. S., Hydrogr., XIV, pp. 15, 11 figs. Stockholm, 1939.

In this important paper the authors describe a continuation of the work which was first reported by Pettersson at the meeting of the International Council in Copenhagen in 1938. A knowledge of the angular distribution of the light at various depths is of value for at least two reasons. In the first place, its variation with depth will give us some idea as to how much of the extinction suffered by the light is due to genuine absorption by the water, by matter in solution, or by dark and opaque matter in suspension, and how much to scattering by reflecting or diffracting particles in suspension. Secondly, a reasonably accurate knowledge of the polar distribution of the light, as obtained by the authors, enables us to find the ratio of the total illumination at any point, as measured by a spherical photometer equally sensitive to light from any direction, to the vertical illumination, as usually measured with a photometer having a plane horizontal diffusing window. This is of interest, since the photosynthetic activity is proportional to the total illumination.

The authors used two types of photometer. In the first the cell was mounted in the usual way behind a horizontal diffusing window, but a horizontal opaque disk, mounted at a variable height centrally above the window, could be used to cut off all light reaching the photometer above any desired altitude. In this way the illumination received from different altitude zones could be found by difference. In the second photometer the effective illumination could be restricted to a comparatively narrow angle by means of suitable diaphragms, and the axis of this cone could be varied both in altitude and in azimuth so as to obtain a complete polar diagram of the illumination. This type obviously affords more information as to the light, and has the advantage that its readings are direct, and not obtained by difference. Its use would seem, however, to be restricted to comparatively calm water.

The results show clearly that in these smooth water conditions, and with the comparatively low-angle direct sunlight in which most of the readings were made, the main sub-surface illumination was restricted to a comparatively narrow cone whose axis was close to the theoretical path of the direct rays. With increase of depth the cone became wider, due to scattering, and its axis more nearly vertical, due to the selective action of absorption in affecting most strongly the more oblique rays. Even at 40 metres, however, although the maximum illumination vector had been reduced to 1/50 of its value at 20 metres, and its obliquity reduced from about 28° to about 20°, the widening of the cone by scattering was not very pronounced, indicating that absorption was, in this case at least, much the more important of the two extinguishing agents.

From their polar curves the authors calculated the ratio of the total to the vertical illumination under different conditions of depth and surface light. They checked their results by comparing the vertical illumination, as calculated from the polar diagram, with that measured with the same photometer without the conical diaphragms, the concordance being very satisfactory.

The ratio total/vertical would be 2.0 if the illumination were uniformly distributed over the whole of the upper hemisphere, none coming from

below, but under water, where low-angle light is relatively weak, the ratio is naturally lower, falling as the light becomes more nearly vertical either due to an increase in the solar altitude or to the differential effect of absorption with increasing depth. The authors give values ranging from 1·51 down to 1·23 according to solar altitude, depth, and colour of the light measured. Red and blue light are both more rapidly absorbed than green, so that they are generally more nearly vertical at a given depth, and their ratio values smaller. By combining the ratio values with the coefficient 1·09 which it has been shown should be used to correct the readings of a photometer with opal window for increased reflection loss when submerged, the authors arrive at a series of coefficients from which the appropriate one may be chosen to obtain, under any given conditions, the total submarine illumination from the reading of a horizontal photometer standardized in air.

This valuable paper will be read with great interest by all concerned in any way with problems of daylight illumination under water.

H. H. P.

M. Uda. "Researches on 'Siome' or Current Rip in the Seas and Oceans." Geophys. Mag., Vol. XI, No. 4, pp. 307—372, 26 figs. Tokyo, 1938 (?).

Nachdem in den letzten Jahren eine Reihe von Untersuchungen über Stromkabbelungen erschienen sind, nimmt die vorliegende Arbeit die in Japanischen Gewässern gemachten Beobachtungen zum Ausgang, um die Erforschung in mehr exakter Richtung zu versuchen. Nach einem geschichtlichen Überblick, der sich auf eine umfassende Literatur stützt, gibt der Verfasser zuerst eine Einteilung der Japan umgebenden Wasserarten in 10 Wasserkörper; ihre Grenzen an der Oberfläche, zugleich die Grenzen der Meeresströmungen und Linien sprunghafter Änderung der Wassertemperatur, erweisen sich als Stellen häufigen Auftretens der Kabbelungen, deren wellenartig sich schlängelnde Form besonders hervorgehoben und durch Zahlen belegt wird. Ein zweiter Abschnitt erweist in grossen Zügen eine weitere Übereinstimmung mit Gebieten starker Wirbelhaftigkeit und starker Konvergenz (oder Divergenz), die auf einer Reihe von Karten dargestellt werden; auch die Linien gleicher Turbulenz führen zu demselben Ergebnisse.

Nach diesen Untersuchungen der Meeresoberfläche entwirft der Verfasser eine Reihe Schnitte aus dem Gebiete, in dem Oyaschio und Kuroschio aneinander grenzen, und beschreibt an ihnen das schräge Hinabgleiten des kalten Wassers unter das warme; die Darstellung berührt sich oft mit Gedankengängen, die aus dem "Meteor"-Werk bekannt sind: in der Tiefenkarte des kalten Wassers, in der Deutung des O_2-Minimums, in Berechnung des Verhältnisses zwischen Austausch und Geschwindigkeit, das im Oyaschio-Unterstrome zwischen 0·4 und 2·4 schwankt. Ein Experiment in einem Tank bestätigt die Konvergenz an der Wasseroberfläche als eine Grenze zweier Zirkulationen, die sich in der Tiefe zugleich als Divergenz darstellt; die künstliche Kabbelung an der Oberfläche erweist sich bei genauerer Betrachtung als eine Kette von nebeneinander liegenden Wirbeln mit senkrechter Achse. Beschreibungen von 14 beobachteten Kabbelungen ergeben zusammen mit den vorhergehenden Ausführungen eine Einteilung in drei Gruppen: 1) Kabbelungen bei Konvergenz verschieden dichter Wasserarten, oft erkennbar durch Anhäufung von Treibgut; 2) Kabbelungen bei Divergenz; auf sie dürften die seltener beobachteten "Ölflecke" zurückzuführen sein; 3) Kabbelungen ohne merklichen Unterschied der Wasserarten zu beiden Seiten der

Unstetigkeit; sie sind dynamischer Art; Verf. beschreibt Kabbelungen in homogenem Wasser über einer Grenzfläche in der Tiefe. Die Erscheinung von Kabbelungen über einem Schelf erklärt er auf Grund der topographischen Wirbelwirkung im Sinne V. W. Ekmans. Ob freilich die Rippeln, die bei einer mit 1·5 kn. wandernden Kabbelung bei ruhigem Wetter beobachtet wurden, von der relativen Geschwindigkeit des Wassers gegen die Luft herrühren, muss bezweifelt werden, da ein so geringer relativer Wind keine Wellen erregen wird. Der Verfasser, der auf die Spärlichkeit von Strommessungen bei Kabbelungen hingewiesen hat, schliesst mit einer Aufzählung von zahlreichen Fragen, die einer künftigen Untersuchung überlassen bleiben müssen.

H. Thorade.

S. F. Grace. "Friction in the Tidal Currents of the English Channel." Roy. Astron. Soc., Geophys. Suppl. Vol. IV, No. 2, pp. 133—142, 1 fig. Edinburgh, 1937.

Der Verfasser untersucht die Gezeitenreibung im Englischen Kanal nach der gleichen Methode, die er ein Jahr vorher auf den Bristolkanal angewandt hat. Doch liegen die Verhältnisse hier verwickelter, wie auch Defant vor einer Reihe von Jahren auf anderem Wege fand. Er behandelt die Strecke von Ramsgate—Calais bis ungefähr Brighton—Le Havre, in der eine Reihe von aufgearbeiteten Strommessungen von Feuerschiffen vorliegen. Die für die Reibung berechneten Werte zeigen ein ziemlich uneinheitliches Bild; immerhin ergibt sich eine wesentliche Verbesserung der vorläufigen Zahlen, die der Verfasser früher (1929) für das "Varne"-Feuerschiff berechnet hatte. Es ist zu beklagen, dass ein früher Tod dem Verfasser die Möglichkeit nahm, den Gegenstand weiter zu verfolgen.

H. Thorade.

H. Pettersson. "Internal Waves in Scandinavian Waters." Comptes Rend. Congrès Internat. de Géogr., Amsterdam, 1938. T. II, Sect. IIb, pp. 77—86, 4 figs. Leiden, 1938.

Nach einer kurzen geschichtlichen Würdigung der Arbeiten von O. Pettersson, seiner ersten Entdeckung interner Wellen von Gezeitencharakter am Eingange der Ostsee (1907) und seiner auf der Station Bornö angewandten Methoden gibt der Verfasser eine Übersicht über die in neuerer Zeit mit einem schwimmenden, an einer Boje aufgehängten internen Pegel erhaltenen Ergebnisse, wie sie namentlich in den Arbeiten von Kullenberg niedergelegt sind. Die durch harmonische Analyse gefundenen Schwingungen sind aufzufassen als eine Reihe fortschreitender Wellen, deren Geschwindigkeit gut zu der mathematisch berechneten stimmt; unter ihnen sind die Wellen mit Gezeitenperiode und die mit der freien Trägheitsperiode besonders bemerkenswert. Zum Schlusse wird hingewiesen auf die aus optischen Messungen hervorgehende Ansammlung von Trübe in und unter der Grenzfläche und die daraus folgende Bedeutung der internen Wellen in biologischer Hinsicht, weil die erzeugten Hebungen und Senkungen diese Nährschicht wechselnden Beleuchtungsstärken aussetzen.

H. Thorade.

E. Hentschel. "Kinetisches und akinetisches Plankton." Die Naturwissenschaften. 27. Jahrg., H. 13, S. 209—211, 1 Fig. Berlin, 1939.

In his treatment of the huge material from the "Meteor" expedition Hentschel succeeded in bringing out certain characteristic differences between the occurrence of the important groups of nannoplankton: coccolithophorides, diatoms, dinoflagellates and protozoa. In the present paper he describes an attempt to obtain a description of actual differences in the behaviour of different groups of plankton organisms on the basis of countings of plankton obtained by his bronze-gauze sieve. A large number of countings is a pre-requisite for using the method which he describes, and which may be briefly explained thus. All the samples are arranged according to the relative number of one of the main plankton groups, for instance the dinoflagellates, and graphed in arbitrary groups as abscissae. The corresponding values for the other plankton groups (diatoms, protozoa . . .) are entered as ordinates and the points for each group combined in a curve. Such curves for diatoms, metazoa and protozoa, based upon material from three different collections, 1) August plankton from Icelandic waters, 2) plankton from the route Orkney Islands—West Iceland from February to October, and 3) plankton from north-west African waters are demonstrated. The curves for the metazoa and the protozoa in all three cases have a fairly linear form, while the curves for the diatoms do not show any common trend. This would indicate that diatoms and dinoflagellates behave in a different way as to numerical occurrence, while the dinoflagellates, metazoa and protozoa according to these data would seem to behave more or less in a similar way. On the basis of his findings as to the relative numerical occurrence in these surface samples, Hentschel proposes to divide the plankton into two groups, "Kinetisches" plankton made up of dinoflagellates, protozoa and metazoa, and "Akinetisches" plankton consisting of the diatoms only.

Such a grouping of the plankton organisms may be of value in pointing out ecological features which ought to be studied more closely. It would seem, however, that the names attributed to these two new groups might have been more happily chosen. According to Hentschel, the names are not supposed to indicate that the ability of locomotion is in any way the cause of the similarity in numerical occurrence, although he does not find it improbable that there may be some connexion between the two. The names kinetic and akinetic plankton might, however, lead to some misunderstanding as to the nature of the ecological classification they represent.

T. Braarud.

T. Braarud and **A. Bursa.** "The Phytoplankton of the Oslo Fjord, 1933—1934." Hvalrådets Skr., Nr. 19, pp. 1—63, 9 figs. Oslo, 1939.

The plankton and hydrography of the Oslo Fjord have been studied for many years, and the results of the first extensive survey were published by Hjort and Gran in 1900. The present paper extends our knowledge of this complicated area. It is based upon a quantitative survey of plankton production, using the sedimentation technique of Utermöhl. Measurements of temperature, salinity, percentage saturation of dissolved oxygen and of the phosphate content are given.

The area may conveniently be divided into the inner fjord (Bonne Fjord, Katten, Oslo Harbour and Lysaker Fjord stations) and the outer (Breiangen,

Rauer and Ferder stations). The Drøbak Sound, with a threshold coming to about 40 m. below the surface, connects the two areas.

In both the inner and outer fjords, plankton production is very scanty during the winter; low light intensity, short days and prevalence of cloud are held to be the factors responsible. In March, there is the spring maximum of diatoms and in both areas; "a quickly growing neritic diatom population (*Thalassiosira—Porosira—Sceletonema* plankton) reaches its maximum in the latter half of March." This early spring plankton is succeeded by a diatom-dinoflagellate population, (*Chaetoceros* and peridinians) and at this time, (April and May) the plankton is "remarkably uniform within the whole of the Fjord."

In May and June, there is a second diatom maximum in the inner area, composed partly of neritic and partly of oceanic species. In the outer area, on the other hand, diatoms decrease in numbers in May and *Pontosphaera huxleyi* may occur in considerable quantity. This difference is illustrated in Tables XIII and XIV, pp. 62 and 63. At Station 100 (Lysaker Fjord), representative of the inner area, the neritic diatom, *Sceletonema costatum,* was absolutely the most numerous species on May 28th, 1934. It made up ca. 93 % of the diatoms found between 1 and 25 m.; diatoms were nearly 30 times more abundant than dinoflagellates. At Station 106 (Ferder), in the outer fjord, on May 29th, 1934, *Pontosphaera huxleyi* was the most abundant species. The dominant diatom was *Rhizosolenia alata,* making up about 75 % of the total diatom population of the upper 25 m. Concentrations of diatoms, however, were much lower than in Lysaker Fjord and this was true also for dinoflagellates, which were about 9 times less numerous than diatoms.

The lower level of phytoplankton production in the outer area is, doubtless, a reflection of the lower phosphate content. At Ferder, the values at depths of 1, 10, and 25 m. were 0·0, 0·06 and 0·24 microg.-atoms P per litre. At Lysaker, comparative values were 0·03, 0·13, and 0·28 respectively. The higher phosphate content of the inner fjord is, presumably, due to the Oslo sewage and some chemical analyses of this effluent would have been helpful. The larger production of diatoms in the inner fjord during May and June, and the generally lower concentrations in the outer, may be due to the exhaustion of silica in the latter area, following the spring diatom maximum. In the inner fjord, the Oslo sewage, with associated storm water overflows, may maintain concentrations of silica at a level sufficiently high to permit diatoms to flourish.

On p. 30, the suggestion is made that "the population of diatoms which succeeds the large and quickly growing species of the spring may be less exacting as regards concentration of nutrient salts" and that this may be a more potent factor than that of temperature. It is further stated that "this must be studied by culture experiments where the two factors, temperature and nutrient salt concentration, may be separated." Analyses of the silica content of either spring and summer forms, or of typically neritic and oceanic species, might throw light on this subject. Additional chemical data, or the cultivation of diatoms under experimental conditions would certainly seem to be needed before the observed differences between the early summer plankton of the two areas can usefully be considered.

This question is further dealt with from the general point of view of the influence of the Oslo sewage (pp. 32—35). The authors are faced with the difficulty that although sewage is discharged at all seasons of the year,

the difference in the plankton of the two areas is mainly to be seen in the summer. The influence of seasonal changes in direction of prevalent winds, with resultant movement of surface water, and the effect of the effluents upon the transparency of the water are described in some detail. It is shown that the vertical distribution of the phytoplankton in summer is different in the two areas. In the outer more than 50 % of the plankton was in the upper 10 m.; in the inner, only 1 % was found below 10 m. (data from table on p. 31).

The influence of the Oslo sewage on the general biological conditions is well illustrated by Fig. 9 on p. 42. In this, the differences between the highest and lowest records of oxygen percentages in the upper 10 m. are shown. The greatest (130) was found at the station in Oslo Harbour; the smallest (16) at Ferder, the furthest station in the outer area. Finally, the authors deal with the effect of the sewage on the composition of the phytoplankton and recognize poly-, meso-, and oligo-saprobic elements.

This area is still under investigation (*vide* pp. 35 and 41) and it is to be expected that some of the points brought to light in the present paper will be considered again. Strictly quantitative plankton studies of this kind involve an enormous expenditure of time and energy on the part of the biologist. Parallel chemical analyses, in comparison, can be carried out so quickly and their value is so great, when the time eventually comes to interpret the biological material, that the day has surely arrived when extensive plankton work should not be undertaken without the fullest support from the chemist.

A. C. G.

J. Henschel. "Vertikale Wanderungen und unperiodische Schwankungen des Copepodenplanktons im Fehmarnbelt, Juni/Juli 1936." Kieler Meeresforsch., Bd. III, H. 1, S. 99—113, 7 Abb. Kiel, 1939.

As a further contribution to the knowledge of vertical distribution in the plankton, Dr. Henschel has collected a number of 2-litre samples of the Copepoda at the Fehmarnbelt Lightvessel over a period of eighteen days in the summer. Contrary to the more usual conditions for such work, there is here a marked stratification due to the presence of fresher surface water from the Baltic and salter deep water from the Skagerak. Typically the boundary lies at 15—20 metres and shows rapid changes for both salinity and temperature, although oxygen values show little relation to the boundary and the light decreases steadily towards the bottom after falling rapidly at first.

Altogether 1491 adult copepods were collected. *Acartia bifilosa* formed 55·5 % of the total and was most abundant at 10 m., extending to the surface. *Pseudocalanus elongatus*, forming 15·4 %, was the second and was most abundant at 20 m., extending from 15 to 25 m. Other significant forms were *Temora longicornis* (maximum at 10 m. and extending from 5—15 m.), *Centropages hamatus* (maximum at 15 m. and extending from 5—15 m.), *Oithona similis* (maximum at 15 m. and extending from 10—15 m.), and *Acartia longiremis* (maximum at 25 m. and extending from 15—25 m.). In addition a few individuals of *Eurytemora hirundo* and *Paracalanus parvus* were found, mainly between the surface and 15 m. depth.

Reviewing the evidence from his own and other data, Henschel suggests that *Acartia bifilosa* and *Eurytemora* were both carried by the Baltic flow, whilst *Pseudocalanus* and *Acartia longiremis* were brought from

the Skagerak. Although *Centropages, Temora* and *Oithona* are also North Sea and Skagerak forms, their general distribution about the lower edge of the upper layer (i.e., in intermediate salinities), together with the generally restricted distributions of the others, lead him to consider the possible migrations of the copepods into optimum physiological zones. He suggests that the particularly limited distribution of *Oithona* may be due to its lesser salinity tolerance, whilst the distribution of *Acartia longiremis* may be related to the lower temperatures of the bottom water as well as to its higher salinity, since it may also be found nearer the surface in the winter-time.

Although the numbers are relatively very small, there is evidence in *Acartia bifilosa* of a distinct diurnal movement, from the 10 m. depth in the daytime to the surface waters at night. Further analysis shows that in general the males had a more limited and deeper distribution during the day whilst the females were more restricted and rather higher during the night. Such diurnal variations were disturbed by the non-periodic changes due to the varying directions and speeds of the two currents, but analysis of these and the associated salinity changes provided further evidence of the Baltic origin of *Acartia bifilosa* and of the salinity effect upon its vertical distribution.

Such work, attempting to show the inter-relationships of different factors, is important in solving the problems of vertical distribution. It would be interesting to see it repeated under rather different conditions, e.g., as Henschel has suggested, in Bornholmbecken, where the relations between the temperature and the salinity boundaries are different. In conditions of greater complexity, it might also be desirable to take larger samples than has been the case here.

C. E. Lucas.

R. Bassindale. "The Intertidal Fauna of the Mersey Estuary." Journ. Mar. Biol. Assoc., Vol. XXIII, No. 1, pp. 83—98, 1 plate. Cambridge, 1938.

Der Verfasser berichtet hier über seine faunistischen Untersuchungen in der Gezeitenregion des Unterlaufs der Mersey, von oberhalb Runcorn Gap (Gezeitengrenze) bis ins offene Meer. Diese Strecke ist gekennzeichnet durch das Vorhandensein ausgedehnter, bei Ebbe trocken fallender Schlick- und Sandbänke, deren Fauna im Sommer 1933 eingehend erforscht wurde; sie zerfällt in zwei Abschnitte; einen oberen, der seewärts bis zum Rock Light reicht, und einen unteren, Liverpool Bay.

Die Bodenfauna des oberen Abschnittes hat einen ausgesprochen mesohalinen Charakter, artenarm aber individuenreich. Bemerkenswert ist das überall häufige Vorkommen von *Nereis diversicolor,* das Vorherrschen auf weicherem Boden von *Clitellio arenarius* und das stellenweise sehr zahlreiche Auftreten von *Pygospio elegans.* Die beiden Polychäten finden sich, zusammen mit *Corophium volutator,* ebenfalls häufig im oberen Abschnitt, auch im unteren Teil des Ästuars, allerdings nur wo der Alt, ein kleiner Fluss, mündet; also ebenfalls in brackischem Wasser. Übrigens ist die Fauna hier rein marin und sehr artenreich. Die schlickigen und aus einer Mischung von Sand und Schlick bestehenden Bänke sind dicht besiedelt; die aus reinem Sand bestehenden sind arm, mitunter ganz steril.

Angaben über den aktuellen Salzgehalt an den über hundert Stationen

fehlen in der vorliegenden Arbeit; der Verfasser verweist für die Hydrographie des Ästuars auf einen 1937 erschienenen Bericht: "Water Pollution Research Technical Paper No. 7." (Department of Scientific and Industrial Research).

H. C. R.

N. H. Howes. "The Ecology of a Saline Lagoon in South-East Essex." Journ. Linn. Soc.-Zoology-, Vol. XL, No. 273, pp. 383—445, 5 figs., plates 8 and 9. London, 1939.

Dieser "lagoon" ist ein kleiner Wasserlauf, New England Creek, im Deltagebiet des Roach, der 1925 durch zwei Dämme sowohl vom Meer als vom oberen Flussteil abgetrennt wurde. Es entstand dadurch ein ungefähr 2·5 km. langer und 50 bis 75 m. breiter, etwas gewundener Kanal, dessen grösste Tiefe nur stellenweise mehr als 3 m. beträgt. Da ihm sämtliches Abflusswasser der nächsten, sehr öden Umgebung zugeführt wird, hat sich der ursprünglich wohl brackische Kanal in ein salzhaltiges Binnengewässer, "saline lagoon", umgewandelt. Der Verfasser hat nun die topographischen Verhältnisse und Milieufaktoren sowie die Flora und Fauna dieses Gewässers in der Periode Januar 1934—März 1935 einmal monatlich recht genau untersucht. Das von ihm festgestellte abweichende Verhältnis der Salzkomponente in Vergleich zu ihrem Verhältnis im Meerwasser hat ihn veranlasst, das Wasser nicht als "brackish" sondern als "saline" anzudeuten, indem er die erstgenannte Bezeichnung ausschliesslich für verdünntes Meerwasser gebrauchen möchte. Es ist nicht ganz klar, weshalb der Verfasser hier von der üblichen Terminologie abweicht, denn bekanntlich ist das Ionenverhältnis der schwach-brackischen, mit Flusswasser stark verdünnten Gewässer ebenfalls ein anderes wie im Meer. Interessant ist es jedenfalls, dass uns hier ein, und zwar seltenes, Beispiel eines modifizierten Brackwassers mit hohem Salzgehalt vorgeführt wird.

Übrigens weisen sowohl die Flora als die Fauna einen typischen polyhalinen Brackwassercharakter auf, wie der im Laufe der genannten Periode zwischen 21·5 und 27·9 $^0/_{00}$ schwankende Salzgehalt erwarten liess. *Ruppia maritima* und *Chaetomorpha linum* bilden ausgedehnte dichte Rasen, die Fauna hat noch vorwiegend marinen Charakter, autochthone (mesohalinophile) Brackwasserbewohner sind nur ziemlich häufig oder selten. Erwähnenswert ist das Vorkommen von *Gobius niger*.

Der dritte Abschnitt dieser inhaltsreichen Arbeit bringt schliesslich eingehende Betrachtungen über den physiologischen Effekt verschiedener Milieufaktoren auf die Fauna als Ganzes, wofür auf das Original hingewiesen sei.

H. C. R.

C. E. Renn. "The Wasting Disease of *Zostera marina*. L. A Phytological Investigation of the Diseased Plant." Biol. Bull., Vol. LXX, No. 1, pp. 148—158, 7 figs. Woods Hole, Mass., 1936.

There are at least three different opinions as to the organism that causes the disappearance of the eelgrass on both the western and eastern coasts of the Atlantic. French investigators, Messrs. Fischer-Piette, Heim and Lami, were the first to report a pathogenetic bacterium as active in the diseased *Zostera* beds. Dr. H. Petersen and Miss I. Mounce described a fungus as the direct cause of the disease, and the author of this

article has found another organism in the diseased plants to which he ascribes a parasitic nature. It is "an unidentified *Labyrinthula,* an amoeba-like organism with mycetozoan affinities." In many features it is similar to members of the family that are found as parasites on marine algae. The spindle-shaped cells and the interconnecting system of pseudopodia may be easily overlooked, as they have only a slight refractility, and their staining is difficult. Moreover they occur in the green tissues beyond the borders of the visible symptons of the disease, the black-brown spots on the epidermis of the leaves. The spindle-shaped cells are 10—20 μ long and 5—8 μ in diameter; the cells can be connected together by a network of pseudopodia, and the spindles are motile. (It may be of some importance to mention here that the same kind of organism is found in Holland in diseased eelgrass: A. van der Werff, "A new parasitic organism in *Zostera marina.*" Chronica Botanica, IV, 1938, p. 498—499). Results of inoculation experiments indicate the parasitic nature of the *Labyrinthula;* healthy plants were inoculated by fastening to their leaves small pieces of diseased leaf. After 24 hours 50 % of the leaves showed symptoms of the disease and invasion of *Labyrinthula,* while after one or two days no bacteria or fungi were found. In the control preparations made by attaching pieces of normal leaf, no symptoms of disease or invasion by *Labyrinthula* were found after one day; after 2 or 3 days, however, a rather important percentage of the controls showed symptoms of disease. This, however, is ascribed to the fact that the control preparations were made on the same leaves as the real inoculations with pieces of diseased leaf, and that after 2 or 3 days the controls were over-run by streaking arising from the inoculated regions. Inoculation experiments with cultured isolated *Labyrinthulae* have not given satisfactory results.

To prove definitely that *Labyrinthula* is the cause of the disease, it seems that further inoculation experiments are needed.

B. Havinga.

Fr. Brock. "Typenlehre und Umweltforschung. Grundlegung einer idealistischen Biologie." Bios, Bd. IX, pp. vii + 40, 12 text-figs. J. A. Barth, Leipzig, 1939. RM 4.20.

We reviewed Dr. Brock's excellent study of the physiology and behaviour of *Buccinum* in a previous number of this Journal (XII, p. 102). The theoretical considerations there advanced on typology and Umwelt theory are more fully dealt with in this very interesting pamphlet, which contains also a full account of Dr. Brock's own work on the respiratory behaviour of the higher Crustacea.

Dr. Brock's paper in our opinion marks a definite advance in Umwelt theory; the psychological implications of the theory are now fully brought out, and the animal is regarded as a subject living in a perceptual world correlative with its needs and its possibilities of action. It responds to "Bedeutungsträger", or objects having elementary meaning or "valence" for it.

Dr. Brock also calls attention to the existence of functional types throughout the animal kingdom, species or groups of species which have similar modes of living, and similar perceptual worlds — as for example the numerous kinds that find their food by smell. The elaboration of this idea may lead to the formulation of an "idealistic biology", complementary to the system of idealistic morphology with its purely structural types.

This is a book which should be read by all who are interested in the physiology and behaviour of animals and in the problems of biological method. The price seems rather high.

E. S. Russell.

C. F. Hickling. "The English Plaice-Marking Experiments 1929—1932." Min. Agric. and Fish., Fish. Invest., Ser. II, Vol. XVI, No. 1, 1937. pp. 80, 35 figs., 1 chart. London, 1938.

These English plaice-marking experiments on the nursery grounds for young plaice in the Southern North Sea between the Haaks and Horns Reef comprised nearly 20,000 fish. First, the dispersion of the marked fish is very clearly shown by charts of the distributions of recaptures. An objective statistical method (the χ^2-test) was used for investigating the question whether there are differences in the distributions of males and females, of older and younger, and of larger and smaller fishes.

After marking there is an initial spread from the position of liberation with a resulting direction more or less to the north-west. Of very great practical and theoretical value is the demonstration of the fact that each part of the nursery grounds supplies recruits to a specific area of the open North Sea, although naturally a pronounced overlapping of these areas is found. Objection on the other hand may be raised to the conclusion that "seasonal changes in the dispersion of the recaptures" — after the initial spread appearing most rapidly in late spring and summer — "are more probably the result of the seasonal changes in the distribution of fishing intensity, themselves chiefly the result of weather conditions". A. C. Johansen, who was well aware of the effect of the movements of the fishing fleet upon the distribution of the recaptures, demonstrated a shoreward movement towards the coast during the first spring months (in the Horns Reef area in March—April). As a matter of fact the quantitative fishing experiments show that in spring the plaice of each year-class on the nursery grounds are very sharply confined within a certain depth curve (in the Horns Reef area 12—20 m.), while in the previous autumn the same year-class had a much wider extension towards deeper water.

The discussion of methods of recapture and seasonal variation gives a most interesting and practically valuable view of the significance of different parts of the nursery grounds for the different nations interested in the fishery.

The rate of recapture was found in each marking experiment to be about uniform year by year, 76 per cent. per annum for the Jutland coast, 70 per cent. off the Frisian coast, and 68 per cent. in the case of plaice marked off the Haaks. The recaptures of fish marked at lengths above 21 cm. in the first year of liberty on the Jutland coast, Heligoland, Frisian coast and round the Haaks were 55, 44, 39 and about 40 per cent. respectively. It might be mentioned that marking experiments on the Dogger Bank carried out by Tåning during 1932 have shown a recapture of about 75 per cent. during the first year of liberty.

As regards growth-rate, on an average the yearly increment in length of plaice in each of the marking experiments was about 3 cm. during the first year after marking, in the second year about 2·8 cm. In no year was there a more rapid growth at all stations than in any other year. Thus maximum growth occurred in the Borkum-Haaks area in 1931, in the Horns Reef area in 1929.

The paper should be studied by every one participating in practical fishery investigations.

Aage J. C. Jensen.

G. Gilson. "Contributions à l'Étude du Hareng 'Guai' dans le Sud de la Mer du Nord pendant les Années 1930 à 1938." Ann. de l'Inst. d'Études Marit. d'Ostende, Mém. No. 4, p. 29, 2 figs. Lierre, 1938.

D'importantes concentrations de harengs apparaissent régulièrement chaque année, de Décembre à Mars, au voisinage de la côte entre le Cap Gris-Nez et l'embouchure de l'Escaut.

Les harengs constituant ces bancs sont "guais" ou vides; ils ont récemment frayé, c'est-à-dire se trouvent en majeure partie aux stades de maturité sexuelle VII-VIII, 1 — VIII, 2 définis par J. Hjort. Cette concentration est régulièrement exploitée par les pêcheurs belges; et, par son retour périodique dans la même région, prend une importance particulière non seulement au point de vue économique, mais encore au point de vue de l'étude biologique générale de l'espèce.

Depuis 1930, le Professeur G. Gilson a régulièrement étudié ces concentrations de harengs guais; le présent mémoire rassemble les diverses communications qu'il a présentées sur ce sujet aux Réunions du Conseil International pour l'Exploration de la Mer.

Ces diverses communications ont trait surtout à la composition au point de vue âge (déterminé par l'étude de l'écaille) des concentrations de harengs guais étudiées et aux conclusions pratiques qu'il est possible d'en tirer quant à la constitution des concentrations futures dans la même région, leur importance et, par suite, le rendement probable de la pêche.

Le stock de harengs présent sur ces pêcheries est constitué par la réunion d'individus adultes issus de pontes annuelles successives (de 3 à 10 ans d'une manière générale). L'ensemble des individus nés au cours de la même saison de ponte constitue une *Classe d'Âge*, dont la valeur représentée par le pourcentage d'individus du même âge présents dans les concentrations, est très différente, de même que l'importance de chacune de ces classes est également variable d'une année à l'autre à leur réapparition dans la même région.

Ces variations se constatent nettement dans les diagrammes columnaires établis à la fin de chaque année d'observations par le Prof. G. Gilson sous le nom d'"*Escaliers Biologiques*".

Mais, parmi ces variations, le Prof. G. Gilson fait une distinction entre la *Fluctuation* des classes et leur *Oscillation*.

Réservant le terme *Fluctuation* à la variation du pourcentage moyen des individus d'une *Classe d'Âge* suivie dans la succession des années, ou à la variation totale de la richesse d'une concentration annuelle (auquel cas il envisage la fluctuation de l'abondance du hareng dans les saisons successives), il désigne sous le nom d'*Oscillation*, la variation, d'une année à l'autre, du pourcentage des individus d'une même génération, depuis leur première apparition dans les concentrations jusqu'à leur disparition et en étudie les modalités.

Nous aurions préféré voir employer ici, au lieu du terme *Classe d'Âge* celui de *Groupe* (Groupe II, Groupe III, etc.) déjà bien défini, pour désigner dans chacune des concentrations annuelles successives les individus d'un même âge bien déterminé, en réservant le terme de *Classe* aux individus d'une même génération qu'il est ainsi possible de désigner par l'année de leur

naissance (Ex: Classe 1936: Harengs nés pendant la saison de ponte 1936, etc.).

On aurait eu ainsi à envisager sans confusion possible, les fluctuations annuelles d'un *Groupe* déterminé et les oscillations annuelles de la valeur d'une *Classe* numériquement désignée, d'autant plus que le Prof. G. Gilson attribue—ce que nous ne pouvons complètement appuyer dans l'état actuel de nos connaissances sur la biologie du hareng—les fluctuations des classes d'âge à la variation des actions externes, tandis qu'à son avis, les oscillations de chaque classe ne dépendent que des causes internes.

Le Prof. G. Gilson admet, en effet, qu'aucune déviation dans le jeu normal des forces naturelles ne saurait exercer une action sélective sur une génération particulière et affecter séparément son pourcentage dans la composition des concentrations annuelles, sans que toutes les autres classes de recrutement soient également affectées de la même manière.

Ceci serait possible si, après la concentration sur les frayères de l'espèce d'individus adultes d'âge différent et appartenant par conséquent à des classes de recrutement distinctes, persistait encore la même formation grégaire jusqu'à la réapparition suivante sur les mêmes frayères.

Or, il a été admis jusqu'à présent, qu'après la ponte, les bancs se dispersaient pour ne se reformer que l'année suivante. Des conditions de cette dispersion, nous ne savons que peu de choses; mais il nous faut admettre, jusqu'à preuve du contraire, que des conditions favorables ou adverses peuvent influer largement sur le comportement des individus d'une classe quelconque, sans affecter pour cela une autre classe dont les individus ont pu se trouver en grande partie dans des conditions de milieu toutes différentes.

Sur ce seul point du travail du Prof. G. Gilson que nous avons ici envisagé, le problème apparaît donc bien complexe. C'est d'ailleurs ce qu'il ressort des conclusions de l'Auteur envisageant la multiplicité des problèmes que pose encore la biologie du hareng. Mais, à côté de ces spéculations scientifiques qui prêteront encore longtemps à d'ardentes discussions, il convient surtout de signaler toute l'importance du travail du Prof. G. Gilson pour la grande régularité des observations qu'il a poursuivies depuis une dizaine d'années sur un abondant matériel nettement déterminé, pour la grande valeur des résultats patiemment obtenus et, enfin, pour les conclusions pratiques qu'il a su en tirer dans l'intérêt de la pêche maritime belge.

J. L. G.

J. van Osten. "The Disappearance of the Lake Erie Cisco — a Preliminary Report." Trans. American Fish. Soc., Vol. 60, pp. 1—11, 1930.

The cisco, or Lake Erie herring, was a very important commercial species of the Great Lakes fisheries. Up to 1925 the "normal" annual catch was about 20 million pounds, though it fell to 13½ million pounds in 1916 and rose to 49 million pounds in 1918. 1923 and 1924 were also very productive, the catch being over 30 and 32 million pounds respectively. In 1925 there was a disastrous collapse, only 5½ million pounds being taken, and by 1928 the fishery was virtually extinct and had shown no signs of recovery by the time this paper was read in 1930.

Van Osten believes, and the available data support his view, that the fishery was ruined by overfishing, which in a lake where control of the fisheries is shared by several States of the U.S.A. and the Province of Ontario, with all the familiar difficulties of "international" control, is not

surprising, but was rather more the fault of the fish than the fishermen. From the statistics of landings at various ports, it appears that up to 1922 the fish were fairly evenly distributed in the lake but in 1923 and 1924, for some unknown reason, the fish congregated in the eastern part of the lake and naturally the fishermen followed them. Since there are grounds for the belief that during these two years the cisco population was about normal, the fact that they were crowded into a restricted area meant that they were easier to catch and it is significant that the average number taken per unit of fishing gear was considerably increased. The result was that in 1923 and 1924 the catch exceeded the normal by 20½ million pounds, an amount almost exactly equal to the average yearly production. Then, early in 1925, the fish, again for reasons unknown, apparently resumed their normal distribution, and there were so few left that their capture was no longer profitable.

If van Osten is right, and the statistical evidence is in his favour, then in time the fishery will recover, and if fishing remains uncontrolled and the unknown factors causing the fish to congregate in one area operate again, the history of the cisco will repeat itself.

F. T. K. P.

V. Tchernavin. "The Absorption of Bones in the Skull of Salmon during their Migration to Rivers." Fisheries, Scotland, Salmon Fish., No. VI, 4 pp., 1 pl. Edinburgh, 1938.

Dr. Tchernavin's valuable work on the breeding changes in the skulls of salmon and trout is well known, and in the present short paper he deals with a matter of considerable interest to zoologists and physiologists alike. He has observed that, while some of the bones of the salmon skull increase in size during the spawning migration, others actually diminish in volume. The bones of this second category include those forming the gill-covers, the branchiostegals, and the post-orbitals. Other bones, such as the supra-ethmoid, may become enlarged in one part and reduced in another. The reduction in the volume of a bone is accomplished by absorption of some of its substance, and the author suggests that, since the parts of the skull growing during the breeding period require a large amount of material, mostly calcium, this is probably derived from the absorbed bones. It may be noted that even those bones that are enlarged do not simply increase in size, but gradually change their shape, so that here also a certain degree of absorption seems to occur.

The present contribution would appear to open up an interesting and probably fruitful field of research, dealing with the whole problem of the calcium metabolism of the salmon at various stages of its life history. It is well known that during the spawning migration the scales are largely absorbed, and Dr. Tchernavin suggests that there is a definite correlation between the degree of growth of the skull bones and teeth and the amount of scale absorption.

J. R. Norman.

L. P. Schultz. "The Breeding Habits of Salmon and Trout." Ann. Rep. Smithsonian Inst., pp. 365—376, 5 pls., 5 text-figs. Washington, D.C., 1938.

There is a very extensive literature dealing with the life histories and breeding habits of salmon and trout, especially of the five species of the genus *Oncorhynchus* found on the Pacific coast of North America, known

collectively as Pacific Salmon. The breeding migrations of these species, which are of considerable economic importance, have been extensively studied, but reliable information concerning the actual spawning activities is not readily available. The careful observations recorded in the present paper should do much to fill this gap in our knowledge. Although these are confined to the little Redfish, a landlocked race of the Sockeye Salmon (*O. nerka*), the nest-building activities are, as the author points out, practically the same for all species of salmon and trout.

Dr. Schultz has shown that the so-called spawning process includes three quite distinct acts on the part of the parent fish, concerned respectively with nest-building, courtship, and actual spawning. Failure to recognize this has been largely responsible for a greater or lesser degree of confusion in the observations of earlier investigators. The construction of the nest, or redd, which is carried out mainly by the female, is described in detail, and an interesting picture is given of the manner in which the cavity intended for the reception of the eggs is excavated. It is pointed out that the fish works upstream, so that as she progressively prepares new cavities some of the material thus disturbed is swept down to cover the eggs deposited in the older redds — a conservation of energy! After describing the methods adopted by both sexes to defend the nest, the author outlines the courting activities, which take place between many of the nest-building acts by the female, but are not accompanied by any spawning acts. These last are shown to be quite distinct, and to require little more than two seconds for their completion. Finally, he deals with the process of "water-hardening" of the eggs after fertilization, the subsequent dangers to which they are exposed, and the post-spawning activities of the parents.

J. R. Norman.

C. V. Otterstrøm. "On Methodical Liberations of Salmon and Trout Fry in Watercourses with Special Reference to the Gudenaa Area." Rep. Danish Biol. Stat. XLII, pp. 1—32, 21 figs. Copenhagen, 1938.

In Denmark, as in this country, the activities of man have denied salmon and sea-trout access to the headwaters of many streams in which they formerly spawned, with consequent damage to the commercially valuable adult stock.

The principal barriers to the ascent of migratory fish are mill weirs, turbines, and pollutions, and whilst they may effectually prevent the ascent of the fish they may not prevent the descent of smolts. This is clearly true of weirs and turbines (which are not so deadly to smolts as is often supposed) and it applies to pollution when it is seasonal and when its season does not coincide with the time of smolt migration, e.g., from a potato mill, causing serious pollution in the autumn only, quoted in this paper. If these barren areas can be artificially stocked, an increased run of smolts to the sea should result and more adults should return to be caught in the sea or estuaries. This paper discusses the problems of stocking streams which would otherwise contain no young salmon or sea-trout.

Otterstrøm recommends that only the smallest streams should be stocked with fry and he is doubtful whether any brook more than one metre wide is suitable. This conclusion is based partly on the fact that these small waters are the natural habitat of fry and partly on the absence of predatory fishes. He divides streams into four classes, those with clean water, free

flow, a gravelly bed and a good food supply, which are pre-eminently suitable, those which are good but not up to this standard in some particular, those which are poor but usable and those which, owing to canalization, stagnation, or the presence of mud, are quite useless. He recommends that the density of stocking of the three usable classes should be:— pre-eminent, 2 salmon or trout fry per square metre of surface; good 1 per square metre; poor, 1 per 2 square metres. The fry are, of course, put out in the spring and he reckons that by the autumn ten per cent. will have survived.

The data on which these figures are based are not given and we cannot therefore judge how far they are generally applicable, but they are interesting, for they are much lower than is generally recommended and the expected survival rate is much higher.

It is noteworthy that Otterstrøm does not recommend the artificial stocking of waters accessible to spawning fish, he apparently, like many others, being not yet convinced that man can improve upon nature when nature has a fair chance.

The last section of the paper deals with the details of stocking policy in the Gudenaa area and is an interesting application of the general to the particular.

F. T. K. P.

E. Sivertsen. "Undersøkelser over forholdet mellem spiss- og bredhodet ål og deres næring." Rep. Norwegian Fish. and Mar. Invest., Vol. V. No. 8, 22 pp., 2 pl. Bergen, 1938.

Seitdem unlängst die bewunderungswürdige Arbeit über die norwegische Seefischerei als Beitrag von Oscar Sund zum Handbuch der Seefischerei Nordeuropas (Bd. VIII, H. la) erschienen ist, hat man mit Überraschung erfahren, dass unter den norwegischen Fischereibetrieben auch der Fang von Flussaal eine beachtliche Rolle spielt, dass er zu Anfang der 30er Jahre dieses Jahrhunderts eine Ausbeute von nahezu 700 t. erreichte, und dass eine weitere Steigerung in Aussicht steht, nachdem neuerdings hoffnungsvolle Fangversuche auch längs der Nordlandküste bis herauf nach Lofoten gemacht wurden.

Dieser Sachverhalt macht es verständlich, dass E. Sivertsen in der Meeresstation zu Flødevig bei Arendal in dem für das Aalvorkommen günstigsten Gebiet der norwegischen Skagerak-Küste an einem Material von fast 1000 Exemplaren Untersuchungen über das Verhältnis zwischen spitzköpfigen und breitköpfigen Aalen und deren Ernährung ausführen konnte.

Die Aale waren zum grösseren Teil Gelbaale, die in See nahe der Küste gefangen wurden; die übrigen wurden in Seen und Flüssen des Gebiets erbeutet, und unter diesen befanden sich 150 Blankaale neben 48 Gelbaalen und 103 Jugendlichen von unbestimmtem Geschlecht. Besondere Beachtung fand der Unterschied zwischen den spitz- und den breitköpfigen Gelbaalen, der in zahlreichen Messungen aufgezeigt werden konnte, unter denen die Übergänge nicht fehlten.

Der Verfasser stellt dabei fest, dass beim Übergang des Breitkopfes in den Blankaal nicht der Kopf und die Kiefer schmaler werden, wie ältere Untersuchungen, besonders von C. G. Joh. Petersen fanden, sondern dass die spitzere Kopfform des Blankaals vorwiegend dem stärkeren Dickenwachstum des Körpers zuzuschreiben ist.

Frühere eingehende Untersuchungen über das Verhältnis von Spitzköpfen

und Breitköpfen, namentlich diejenigen von E. Walter und die sehr aufschlussreichen von H. Törlitz (Zeitschr. f. Fischerei, Bd. 21, 1922.) scheinen dem Verfasser nicht vorgelegen zu haben.

Die Untersuchung des Mageninhalts der in See gefangenen Aale zeigte, dass Kruster (besonders *Carcinus maenas*) und zum Teil auch kleine Fische die wichtigsten Nährtiere sind. Es bestätigt sich, in gewissem Grade, dass die Breitköpfe Fisch und die Spitzköpfe Kruster als Nahrung bevorzugen. Im Frischwasser bilden Insektlarven und kleine Schnecken die Hauptnahrung.

Eine weitere Auswertung des Untersuchungsmaterials steht noch aus. Im besonderen sind die Altersbestimmungen mit Hilfe der Otolithen einstweilen auf unerwartete Schwierigkeiten gestossen.

E. Ehrenbaum.

J. Hjort and **J. T. Ruud.** I. "Deep-Sea Prawn Fisheries and their Problems." II. "A Bottom Sampler for the Mud-Line." Hvalrådets Skr. No. 17, pp. 151, 21 figs., 1 plate. Oslo, 1938.

I. In studying the influence of human activity on the stock of whales, in which problem technical and "capitalist" factors play an important part, it was found of interest to compare this fishery with another in which these technical factors play the smallest possible part. For this purpose the fishery on the deep-sea prawn, *Pandalus borealis,* was chosen, in which the normal industrial unit is a small boat and a crew of one or two.

The prawn fishery began in 1898 after the successful fishery experiments of Hjort in 1897. The yield of the prawn fishery was not included in the statistics of "Norges Fiskerier" before the year 1908. In that year the production was 405,800 kg.; in 1935 3,387,000 kg. were caught in Norway (besides 1,239,000 kg. in Sweden and 200,000 kg. in Denmark). The value of the Norwegian catch is in recent years about 2 million kroner per annum. The most common type of craft for prawn trawling is a 30—40 foot cutter, with an engine of 12—20 HP.; more towards the open sea 50—60 foot boats with an engine of 70—80 HP. are also used.

The fishery began in the east of Norway (Langesund and Oslo Fjord) but has now expanded in a westerly and northerly direction as far as Tromsø.

The greatest quantities are fished at depths between 100—250 m. *Pandalus borealis* is only rarely found in water with a temperature below 0° and above 8° C., though the salinity can vary between 33 and 35 $^0/_{00}$. It is caught on a muddy bottom, but it is a general experience that the greatest catches are made close to the rocky sides of the mud. During daytime the prawn live in contact with the bottom, but as soon as the light begins fading, they rise to the higher water layers. The downward migration sets in before midnight, and does therefore not wait for any impulse from increasing light. The food consists of remains of dead animals and plants: *Polychaeta, Holothuroidea, Porifera, Copepoda, Radiolaria, Foraminifera, Diatomea, Peridinea.* The young ones remain for some time in comparatively shallow water; in January or February, when they are 46—64 mm. long, they mix with the older year-classes.

As the occurrence of the prawns proved to be closely related to a soft stratified bottom, the Echo Sounder can be of much help in finding good prawn grounds, this giving a multilined outline in the echogram.

The ovaries begin to ripen at the end of July; spawning takes place principally in October and November, and hatching in March. The young

larvae are 5 mm. long, the last (6th) pelagic stage is 17 mm., and the smallest bottom stage is 21 mm. The larval development takes about 3 months, the number of larvae in the pelagic net samples was, however, exceedingly small, namely, 33. In May, at an age of 1 year, the young are 78—81 mm. long, and at 2 years old they are 105 mm.; they have then in the previous autumn functioned as males. In the next autumn, when they become females and carry eggs, the growth is slow. At 3 years old the length is 117 mm. The endopodite of the first pleopods in the males — that is developed as a copulation organ — is in 4 moultings transformed into the female form.

The prawn grounds have everywhere proved to be populated by the same kind of fishes — a detailed list of which is given — and lower animals; this holds good not only for the Scandinavian waters, but also for the other side of the Atlantic (Gulf of Maine).

The trawling for prawns is only to a very small degree injurious to the young of commercial fish, as these do not live in deep water. The stock of prawns is in many places much affected by the trawling; on some of them the stock in 1905—1906 was 4—5 times as large as in recent years. Much damage is done by the fine-meshed trawls, in which great quantities of small prawns are caught that are not yet mature or at least are not yet beyond the male stage. Experimental fishing with meshes of 12, 14 and 16 mm. from knot to knot in the cod-end proved that 14 mm. was the best size; with a larger mesh many large prawns escape. The authors therefore recommend a minimum size of mesh of 14 mm. At present a maximum size is prescribed, in order to avoid the prawn-trawl being used as a common fish trawl.

II. The bottom sampler described by the authors is a modification of the Pettersson bottom sampler which can be manipulated more easily from a small vessel. It consists of a tube that can be closed at the upper end by a rubber ball; a weight drives the tube into the mud. When the tube is lowered the flow of water will raise the ball, and close it again when it is hauled. Tubes with a diameter of 5—15·5 cm. were used. The sampler is only suitable for a bottom that is neither too soft nor too hard. It can give samples of water immediately above the bottom, and by means of a bundle of glass tubes of different lengths samples of water of varying depths may by drawn. For details the reader is referred to the original description and diagrams.

B. Havinga.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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